

Published in the United States of America

2023 • VOLUME 17 • NUMBER 1/2

# AMPHIBIAN & REPTILE CONSERVATION



[amphibian-reptile-conservation.org](http://amphibian-reptile-conservation.org)

ISSN: 1083-446X

eISSN: 1525-9153



**Front cover:** Falk's Blue-headed Tree Agama (*Acanthocercus* cf. *cyanocephalus*) from south-eastern Angola. Photographed during an expedition to elucidate the biodiversity of south eastern Angola with the Okavango Wilderness Project, in association with National Geographic. A different photograph of this individual appeared as Fig. 2 in an article cataloging the lizards identified during that Project, which was published as: *Amphibian & Reptile Conservation* 16(2) [General Section]: 181–214 (e322). Photo by Chad Keates.





# An annotated checklist of the herpetofauna of the Sibiloi National Park in northern Kenya based on field surveys

<sup>1,2,\*</sup>Sebastian Kirchhof, <sup>3</sup>Victor Wasonga, <sup>4</sup>Tomáš Mazuch, <sup>5</sup>Stephen Spawls, and <sup>3,\*</sup>Patrick Kinyatta Malonza

<sup>1</sup>Division of Science, New York University Abu Dhabi, Abu Dhabi, UNITED ARAB EMIRATES <sup>2</sup>Museum für Naturkunde, Leibniz Institute for Evolution and Biodiversity Science, Invalidenstr. 43, 10115 Berlin, GERMANY <sup>3</sup>Herpetology Section, National Museums of Kenya, P.O. Box 40658-00100, Nairobi, KENYA <sup>4</sup>Department of Forest Ecology, Mendel University in Brno, 61300, Brno, CZECH REPUBLIC <sup>5</sup>7 Crostwick Lane, Spixworth, Norwich, NR10 3PE, UNITED KINGDOM

**Abstract.**—The xeric Lake Turkana area in northern Kenya is often referred to as the “Cradle of Mankind” due to the abundance of hominin fossils. Sibiloi National Park in the Turkana Basin has been well studied for its fossils, but the extant biodiversity of the park remains largely under-surveyed. Today, the ecosystem is threatened by climate change, increasing human population pressure, poaching pressure, overgrazing by domestic stock, and a series of major hydropower dams and irrigated agricultural schemes (particularly the Gilgel Gibe III Dam) in Ethiopia, which may have a negative impact on the water supplies of the lake. The Turkana Basin has a high diversity of arid land herpetofauna, particularly terrestrial geckos. However, due the region’s remoteness many expected species have never been recorded within the National Park. Here we provide an annotated list of the rich reptile and amphibian fauna based on two recent field surveys, including multiple first records for Sibiloi National Park. The surveys yielded records for 34 species, including six amphibians and 28 reptiles (one fresh water turtle, one crocodile, 18 lizards, and eight snakes). In total, 49 species of herpetofauna are currently known for Sibiloi National Park, including eight amphibians and 41 reptiles (three fresh water turtles, one crocodile, 25 lizards, and 12 snakes). Of those, five species are protected by the Convention on International Trade in Endangered Species (CITES; Appendices I, II, or III), i.e., *Trionyx triunguis*, *Crocodylus niloticus*, *Varanus albigularis*, *Varanus niloticus*, and *Eryx colubrinus* (all Appendix II). Three species are listed on the International Union for Conservation of Nature (IUCN) Red List (Vulnerable, Data Deficient), i.e., *Sclerophrys turkanae*, *Trionyx triunguis*, and *Pelusios broadleyi*. Two species (one toad, *Sclerophrys turkanae*, and one terrapin, *Pelusios broadleyi*) are endemic to Kenya and most likely endemic to the vicinity of Lake Turkana. Overall, the herpetofauna of the Sibiloi National Park already seems to be negatively affected and is further threatened by climate change and land use activity. Furthermore, the area comprises a number of CITES listed and IUCN Red List species other than the herpetofauna, including endemics, that warrant protection and conservation measures to prevent further defaunation.

**Keywords.** *Amphibians, climate change, conservation, field body temperature, Lake Turkana, land use, pastoralism, reptiles, Turkana Basin Institute*

**Citation:** Kirchhof S, Wasonga V, Mazuch T, Spawls S, Malonza KP. 2023. An annotated checklist of the herpetofauna of the Sibiloi National Park in northern Kenya based on field surveys. *Amphibian & Reptile Conservation* 17(1/2) [General Section]: 1–18 (e324).

**Copyright:** © 2023 Kirchhof et al. This is an open access article distributed under the terms of the Creative Commons Attribution License [Attribution 4.0 International (CC BY 4.0): <https://creativecommons.org/licenses/by/4.0/>], which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited. The official and authorized publication credit sources, which will be duly enforced, are as follows: official journal title *Amphibian & Reptile Conservation*; official journal website: [amphibian-reptile-conservation.org](http://amphibian-reptile-conservation.org).

**Accepted:** 3 November 2022; **Published:** 1 June 2023

## Introduction

Reptiles and amphibians are currently considered to be among the world’s most endangered groups, with 40.7% of amphibians and 21.1% of reptiles threatened with extinction (Cox et al. 2022). This is perhaps attributed to the fact that they are sensitive to habitat destruction and fragmentation, various environmental

changes, pollution, and climate change. Such threats are linked to both anthropogenic activities and natural causes. In East Africa, the distribution ranges of many amphibians and reptiles are still poorly known due to the vast areas that have yet to be explored by herpetologists (Spawls et al. 2018; Tolley et al. 2016). Nevertheless, even the limited herpetological research conducted to date clearly indicates a high diversity of amphibians and reptiles in East Africa, including

**Correspondence.** [sebkirchhof@gmail.com](mailto:sebkirchhof@gmail.com), [malonzapk@gmail.com](mailto:malonzapk@gmail.com)

## The Herpetofauna of Sibiloi National Park, Kenya

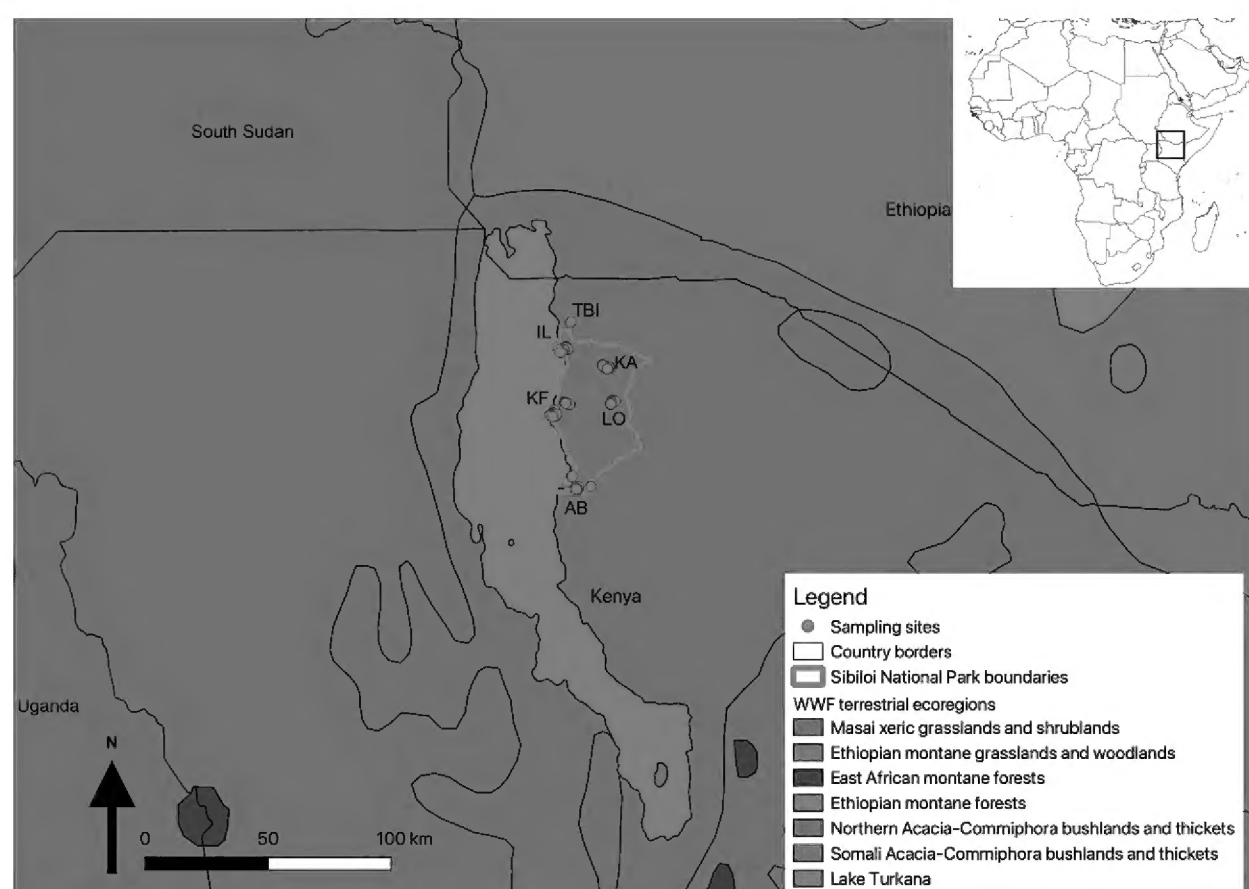
many threatened and endemic species (Channing and Howell 2006; Largen and Spawls 2010; Spawls et al. 2018, 2019; Tolley et al. 2016).

Sibiloi National Park (SNP) is located in Marsabit County in northern Kenya and about 1,570 km<sup>2</sup> in size (Fig. 1). The park lies in the xeric Gregory Rift (the eastern branch of the East African Rift fracture system) on the northeastern shore of Lake Turkana (formerly Lake Rudolf), the largest permanent desert lake and the largest alkaline lake on Earth. The lake is part of an endorheic basin, with three rivers (Omo, Turkwel, and Kerio) supplying most of the lake's water, and it has no outflow. The area is often referred to as the "Cradle of Mankind" because it is quite famous for its hominin fossils, in particular *Australopithecus* and early *Homo* fossils. The park was established in 1973 by the government of Kenya, mainly for the protection of its paleontological sites, and was named for Mount Sibiloi which is located at its southern boundary. Together with the South Island and the Central Island National Parks, the Lake Turkana National Parks were declared as a UNESCO World Heritage site in 1997. The site was listed as a World Heritage Site in Danger in 2018, mostly owing to large-scale transfrontier hydrological projects, in addition to climate change, increasing human population pressure, poaching pressure, and overgrazing by domestic stock.

The Lake Turkana area is characterized as a desert and xeric shrubland biome (Somali-Maasai xeric grasslands and shrublands ecoregion; Olson et al. 2001), and contains a variety of different habitats (Fig. 2). The area is surrounded by *Acacia* (now *Vachellia*)-*Commiphora* bushland and thicket (Olson et al. 2001), bordering the Chalbi Desert to the East, and elevations range from around 340 m to 550 m (Thorsell 2003).

The plains are dominated by sand, silt, and gravel and are interspersed with volcanic formations, which include Mount Sibiloi and its remains of an approximately 7 MYA old petrified forest (Thorsell 2003). The climate is generally hot and dry, with the annual rainfall of about 250 mm mainly restricted to March and April (Thorsell 2003). Temperatures at the nearest weather station in Lodwar on the western side of Lake Turkana average 32 °C throughout the year, with an average annual maximum of 37 °C and average annual minimum of 26 °C (Mbaluka and Brown 2016). There are six major ethnic groups living adjacent to the eastern side of the lake, including the Daasanach, Gabbra, Turkana, Elmolo, Rendille, and the Samburu (Kaijage and Nyagah 2009). Pastoralism (mainly goats and sheep, but also cattle, donkeys, and camel), agro-pastoralism, and fishing are the main sources of livelihood for the local population. Due to the ever-growing population around the lake, these land use practices together with frequently occurring droughts have a degrading impact on the habitats of the area.

The vegetation is dominated by perennial and annual grassy plains and dwarf shrublands, covered with the grass *Aristida* sp. and the common dwarf shrubs *Indigofera spinosa* and *Duosperma longicalyx* (Mbaluka and Brown 2016). Much of the lake shoreline is occupied by perennial grasslands with the halophyte *Sporobolus spicatus* and *Dactyloctenium* sp. (Mbaluka and Brown 2016). However, large parts of the shoreline in the study area are completely devoid of vegetation or scattered with dead reed tussocks in some areas. Woodlands and forests are only associated with ephemeral streams and are dominated by *Vachellia tortilis* (Mbaluka and Brown 2016).



**Fig. 1.** Location of Sibiloi National Park (UNEP-WCMC and IUCN 2022) in Kenya and the main study sites: IL (Ilkemere), KA (Karare), KF (Koobi Fora), LO (Lomoshia), AB (Alia Bay), and TBI (Turkana Research Institute). The inset map shows the African continent, and the black square indicates the location of the enlarged map.



According to the latest IUCN Conservation Outlook Assessment for the area (IUCN World Heritage Outlook 2020), the local mammal fauna is largely depleted. Notably, the hippopotamus, wild dog, lion, cheetah, Reticulated Giraffe, Grevy's Zebra, and Lelwel Hartebeest are species which were formerly abundant there but are now considered rare, endangered, or locally extinct. Historical data indicate that the lake once supported the world's largest colony of Nile Crocodile, but recent field observations suggest the crocodile population is a fraction its former size, likely due to increasing anthropogenic pressures (IUCN World Heritage Outlook 2020). The lake is rich in fish (47 species; Birdlife International 2022). In addition, Lake Turkana is an internationally recognized Important Bird Area (Birdlife International 2022), with 84 water bird species, including 34 Palearctic migrants, according to the latest available data.

The only known extensive reptile and amphibian survey of the area was conducted by Ziliani et al. (2006). The results were presented at the 6<sup>th</sup> Congresso Nazionale della Societas Herpetologica Italica in 2006, but have not been formally published other than the abstract of that presentation and a new species description (Sindaco et al. 2007).

The annotated checklist provided here is the result of two six-week herpetological surveys of the SNP conducted in 2016 and 2017. In addition, the species recorded by Ziliani et al. (2006) are included and discussed. The identifications of the new materials collected in the present study were based on the species descriptions and other literature, morphological comparisons using the reference collection at the National Museums of Kenya (NMK) and, in some cases, the advertisement calls of amphibians (S. Kirchhof, unpub. data).

## Material and Methods

Two expeditions to SNP were conducted from 7 November 2016 to 11 December 2016 and from 28 March 2017 to 24 April 2017. Three observers sampled a total of five sites across the National Park, three along the Lake Turkana (L) shoreline, i.e., Alia Bay (AB), Koobi Fora (KF), and Ilkemer (IL), and two further inland, i.e., Karare (KA) and Lomosia (LO) (Fig. 1). The LO site was only surveyed in March/April 2017. At each site close to the lake, we walked three transects (one in grassland (G) along the shore, one in bushland (B), and one in a dry riverbed (R); Fig. 2), each with a length of about 800–1,000 m, for 3 hours in the morning from 0800–1100 h and 4 hours in the evening/night from 1700–1900 h and 2100–2300 h, and this pattern was repeated over 2 days for each site. At the inland sites, the same protocol was followed, but the grassland transect was replaced with a second bushland transect. In addition, opportunistic collections were made at the Turkana Basin Institute (TBI) near Illeret. The localities of all individuals of reptiles and amphibians were recorded with a GPS (coordinates in latitude, longitude, datum WGS 1984, in decimal degrees), time of day was documented, and a brief



**Fig. 2.** Representative examples of typical habitats within the surveyed transects in the study area: (A) cattle grazing on the grassland transect in KF; (B) bushland transect with compact soil and loose rocks and stones in KF; (C) overgrazed grassland transect at IL; (D) LO bushland transect; (E) AB bushland transect; (F) dry lagga and adjacent riverine vegetation as part of the KF river transect; (G) KA riverbed after rain; and (H) section of the IL river transect.

description of the locality was given. When possible, air, substrate/water and cloacal temperatures were recorded and they are reported here. All temperature were taken by means of a K-type thermocouple (B + B Thermotechnik, effective measurement range -50 to +260 °C) connected to a digital thermometer (Center 300) (accuracy  $\pm 0.1\%$  +0.7 °C, resolution 0.1 °C, effective measurement range -200 to +1,370 °C). Body temperatures ( $T_b$ ) were measured by means of cloacal temperature with the thermocouple inserted 10–15 mm into the animal's cloaca.

Taxonomy follows information from Amphibiaweb (<https://amphibiaweb.org>), Channing and Howell (2006), Frost (2022), Largen (2001), Uetz et al. (2022), and Spawls et al. (2018, 2019). Selected individuals were collected as voucher specimens; and when necessary, individuals were euthanized using an aqueous solution of benzocaine (20%) injected into the body cavity. After injection, the individuals were measured, a tissue sample (liver or muscle from dissected individuals, tail tips from lizards, a ventral scale clip from snakes, and toe clips from frogs) was taken and transferred to ethanol (96%) for possible future molecular analysis, and the specimen was fixed in 2% formalin. After the expedition, voucher specimens and tissue samples

were accessioned into the herpetology collection at NMK. For each species account, NMK numbers and/or field numbers (for the tissue samples from voucher specimens, the specimen number is used, additional tissue samples without vouchers are listed separately), CITES status (where applicable), and any IUCN Red List status other than Least Concern are provided in the header of each species account.

## Results

In total, we recorded 34 species, including six amphibians (Fig. 3) and 28 reptiles comprised of one freshwater turtle, one crocodile, 18 lizards, and eight snakes (Fig. 4). Many taxa in the area currently have multiple subspecies that warrant rigorous revision, so only the binomial names (genus plus species epithet) are used in this list. For each voucher specimen collected and listed here, tissue samples in 96% molecular grade ethanol are available at the NMK, and these samples can be used in future taxonomic analyses.

## Species Accounts

### Amphibia

#### Anura

#### Bufonidae

#### Lugh Toad

##### *Poyntonophrynus lughensis* (Loveridge, 1932)

Vouchers: NMK-A1824 (field no. SK1112)

Localities in the study area (henceforth simply called localities): Turkana Basin Institute (TBI)

Remarks: On 28 March 2017, tens to hundreds of individuals were calling in the late morning (0900–1100 h) together with *Tomopterna wambensis* in a temporary water body created by recent rainfalls in the usually dry bushland in front of the TBI near Illeret. Several pairs of *Poyntonophrynus lughensis* were found in amplexus. One female was collected and accessioned in the NMK collection (Fig. 3A). Similar to other members of the African pygmy toads of this genus, the natural history of *P. lughensis* is almost completely unknown (Ceriaco et al. 2018). Interestingly, in a recent large-scale molecular phylogeny of African toads, *P. lughensis* actually clustered with the species of the genus *Mertensophryne* Tihen, 1960 (Liedtke et al. 2017).

#### Sub-desert Toad

##### *Sclerophrys xeros* (Tandy, Tandy, Keith, and Duff-MacKay, 1976)

Vouchers: NMK-A1817 (field no. SK1118)

Localities: TBI

Remarks: One male was calling on 13 April 2017 in an artificial water reservoir at TBI. This was the only individual we recorded of this widespread species from dry savanna and semi-desert. The specimen (Fig. 3B) showed the bright scarlet vermiculation on the posterior femoral integument typical for *S. xeros*. In addition, the call resembled typical *S. xeros* calls.

#### Turkana Toad

##### *Sclerophrys turkanae* (Tandy and Feener, 1985)

IUCN Red List: Data Deficient

Vouchers: NMK-A1816 (field nos. SK16 1057, SK16 1059, SK16 1060–1064)

Localities: AB (R), KF (G)

Remarks: Endemic to Kenya. This toad (Fig. 3C) was very abundant in the grassland transects along the shores of Lake Turkana, and found in high numbers and different sizes at Alia Bay and Koobi Fora. During the day they were hiding in moist mud cracks, and at night they were on land in slightly flooded grassy plains right at the lake edge. Males were calling in November, and the calls affirmed their identification as *S. turkanae*. According to the latest published amphibian guide (Spawls et al. 2019), this species is only known from Lake Turkana. The IUCN assessment mentions records from two localities in north-central Kenya: Loyangalani [Loiengalani] (south-eastern shores of Lake Turkana), and Uaso Nyiro River in the Samburu Game Reserve (IUCN SSC Amphibian Specialist Group 2016).

## Ptychadenidae

#### Nile Ridged Frog

##### *Ptychadena nilotica* (Seetzen, 1855)

Vouchers: NMK-A1818 (field nos. SK16 1045, SK16 1046, SK16 1056, SK16 1058, SK16 1065–1068, SK16 1070, SK16 1097, SK16 1105)

Localities: IL (G), AB (R), KF (G)

Remarks: This species (Fig. 3D) was found in high numbers. Individuals were found at night together with *Sclerophrys turkanae* in flooded grassy plains along the shore of Lake Turkana, but also on the edge of temporarily flooded waterbodies and in the riverbed transects slightly further away from the actual lake shore where *S. turkanae* was mostly absent. When disturbed at the water edge on land, individuals of *P. nilotica* escaped by jumping into the lake, but instead of diving into the water, they rather jumped across the water surface for several meters without sinking before jumping back on land.

#### Schilluk Ridged Frog

##### *Ptychadena cf. schillukorum* (Werner, 1907)

Vouchers: NMK-A1825 (field no. SK16 1105)

Localities: IL (R)

Remarks: *Ptychadena schillukorum* currently has a large distribution range across sub-Saharan Africa, from Mauritania to Somalia and south to Angola and Mozambique. The taxonomy of frogs referred to as *P. schillukorum* is unresolved, and this taxon may actually represent a species complex (e.g., Nago et al. 2006). We assigned individual SK16 1105 (Fig. 3E) to *P. cf. schillukorum* based on the following features: skin of the flank granular or warty, tympanum-eye diameter ratio about 0.70, both internarial distance and nostril-tip of snout distance less than nostril-eye distance.



A previous record from the Omo River delta in Ethiopia already exists. On the night of 9 December 2016, the sole individual SK16 1105 was found sitting on soft sand in the dry riverbed of an ephemeral river (known as “lagga” or “lagha”), about 1.6 km from the lake shore. In arid lands, this species usually inhabits permanent water bodies such as swamps and springs where they can occur in sympatry with *P. nilotica* (e.g., in Shompole swamp, Magadi, southwestern Kenya) (PK Malonza, pers. obs.). Molecular analyses will help to resolve the taxonomic status of the *P. schillukorum* group.

### Pyxicephalidae

#### Wamba Sand Frog

***Tomopterna wambensis* Wasonga and Channing, 2013**

Vouchers: NMK-1815 (field nos. SK16 1024, SK16 1071, SK16 1084, SK 1111)

Localities: IL (G, R), KA (R), KF (R), LO (R), TBI

Remarks: This medium-sized, stout, semi-fossorial frog was quite common in the study area. Its inner metatarsal tubercle is used for digging into the soil of dry riverbeds in order to reach moister areas and survive droughts, and the outer metatarsal tubercle is absent. It can be further identified by its interrupted glandular ridges below the tympanum.

As soon as a few drops of rain fell – often during the night – the buried individuals of *T. wambensis* (Fig. 3F) appeared on the surface. On 28 March 2017, tens to hundreds of individuals were calling in the late morning (0900–1100 h) together with *Poyntonophrynus lughensis* in a temporary water body created by recent rainfalls in the usually dry bushland in front of the TBI. For one individual, an internal field body temperature ( $T_b$ ) of 29.4 °C was recorded at an air temperature ( $T_a$ ) of 30 °C and substrate temperature ( $T_{sub}$ ) of 21 °C.

### Reptilia

#### Testudines

#### Trionychidae

#### Nile Soft-shelled Turtle

***Trionyx triunguis* (Forskål, 1775)**

IUCN Red List: Vulnerable. CITES App. II

Vouchers: None

Localities: KF (B)

Remarks: The carapace of one dead individual of this soft-shell turtle was found about 900 m from the shore of Lake Turkana at Koobi Fora. These turtles are still eaten by the local people around Lake Turkana (V. Wasonga, pers. obs.; Spawls et al. 2018), so we suspect the locality does not reflect the individual’s actual habitat. The Nile Soft-shelled Turtle inhabits permanent lakes, dams, and rivers, and is known to enter the sea, but it does not live in any other Kenyan lake in the Great Rift Valley other than Lake Turkana, because none of the other rivers were ever connected to the Nile system (Spawls et al. 2018).

### Crocodylia

#### Crocodylidae

#### Nile Crocodile

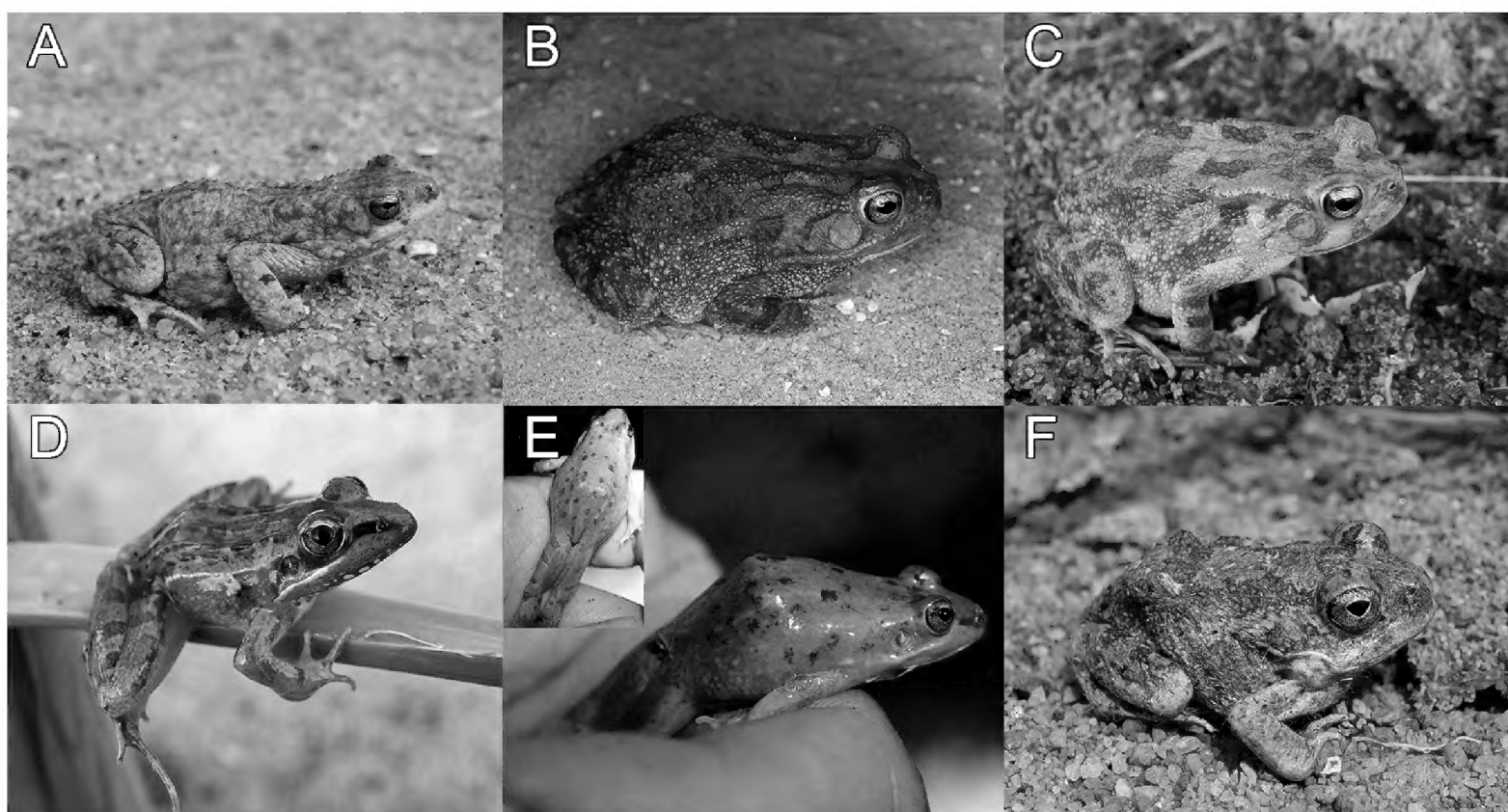
***Crocodylus niloticus* Laurenti, 1768**

CITES App. II

Vouchers: None

Localities: AB (L), IL (L, B), KF (L, G)

Remarks: The Lake Turkana population of Nile Crocodiles used to be the largest in the world (IUCN World Heritage Outlook 2020). Recent data suggests that the crocodiles are heavily impacted by local fishermen who destroy nesting sites, and the remaining population is only a fraction of what it used to be (IUCN World Heritage Outlook 2020). We found *Crocodylus niloticus* in Lake Turkana and adjacent water bodies along the shoreline. Very young juveniles (Fig. 4A) were found in March/April.



**Fig. 3.** Amphibian species recorded during the surveys: (A) *Poyntonophrynus lughensis*; (B) *Sclerophrys xeros*; (C) *Sclerophrys turkanae*; (D) *Ptychadena nilotica*; (E) *Ptychadena* cf. *schillukorum*; and (F) *Tomopterna wambensis*.

## Squamata Agamidae

### Red-headed Rock Agama

#### *Agama lionotus* Boulenger, 1896

Vouchers: NMK-398L/1 (SK16 1038b), 399L/1–2 (field nos. SK16 1114–1115)

Distribution: AB (R), petrified forest

Remarks: The distribution of this taxon is still uncertain in many parts of its range because of possible confusion with *Agama agama* (but not in Kenya), *A. finchi*, and *A. dodomae* (Spawls et al. 2018).

This agama was only found in Alia Bay (three individuals including one juvenile NMK-398L/1 (SK16 1038b)) and in the petrified forest (NMK SK1115). In the absence of rocks, this species was entirely arboreal, living on *Vachellia* sp. trees in the riparian woodlands along the dry riverbeds. Only in the rock-dominated petrified forest site (about 5 km from Karsa Gate, the southern entry point of SNP) was this species rupicolous. We found *Agama lionotus* individuals (Fig. 4B) only between 1800 h and 2100 h. The average  $T_b$  was  $33.8 \pm 1.7$  °C (32.6–35 °C; N = 2) with  $T_{sub}$  ranging from 30–34 °C and  $T_a$  ranging from 32–35 °C.

### Rüppell's Agama

#### *Agama rueppelli* Vaillant, 1882

Vouchers: NMK-375L/1–4 (field nos. SK16 1042, SK16 1074, SK16 1075, SK16 1094)

Distribution: AB (B), KA (B, R), KF (R), LO (B)

Remarks: This species occurs in dry savannas and semi-deserts in lower elevations (Spawls et al. 2018). We recorded 25 individuals of this strictly terrestrial agama (Fig. 4C) in bushland at all sites except IL. Activity was high during all four study months, and individuals were observed to be active from 0900 h to 2200 h. The average  $T_b$  was  $31.9 \pm 3.0$  °C (28.4–36.5 °C; N = 5) with  $T_{sub}$  ranging from 24–39 °C and  $T_a$  ranging from 27–36 °C.

## Eublepharidae

### Somali-Maasai Clawed Gecko

#### *Holodactylus africanus* Boettger, 1893

Vouchers: NMK-390L/1–3 (field nos. SK16 1080, SK16 1081, SK16 1083)

Distribution: KA (R), IL (R), TBI

Remarks: Very little is known about this nocturnal terrestrial eyelid gecko and only occasional records exist. It is assumed to occur throughout dry savannas and semi-deserts from southeastern Ethiopia, northern Somalia through Kenya and into northeastern Tanzania at low elevations of 200–1,000 m (Spawls et al. 2018). We found seven individuals in November, December, and April in dry sandy river beds at KA and at TBI near the water reservoir. The species' occurrence seems to be associated with high groundwater and/or dense vegetation as all individuals were found at night in the riverbed at the edge of the vegetated slope. Three different color morphs were found, including yellowish, slightly pink, and darker brown (Fig. 4D). These are the first Kenyan records from the eastern side of Lake Turkana.

## Gekkonidae

### East African House Gecko

#### *Hemidactylus angulatus* Hallowell, 1852

Vouchers: NMK-380L/1–3 (field nos. SK16 1110, SK 1116, SK16 1055)

Localities: KF (B), TBI, petrified forest

Remarks: This is a fairly large gecko that is widespread in Kenya, occurring south to Tanzania, north to Sudan and west to Senegal, and occupying a variety of dry and mesic habitats (Spawls et al. 2018). It can be distinguished from *H. ruspolii* and other *Hemidactylus* by small granules covering the upper surface of the snout rather than large and keeled granules, heterogeneous dorsal scales with small granular scales interspersed with rows of large, keeled, and mainly oval tubercles, and males with a series of 20–46 preano-femoral pores interrupted mid-ventrally (Fig. 4E). Three individuals were found over the course of our study, and all of them were associated with rocks or anthropogenic structures/houses. This taxon might actually represent a species complex (the type locality is in Gabon), and extensive molecular analyses are necessary to resolve its status. One gravid female carrying eggs was collected on 7 April 2017.

### Barbieri's Turkana Gecko

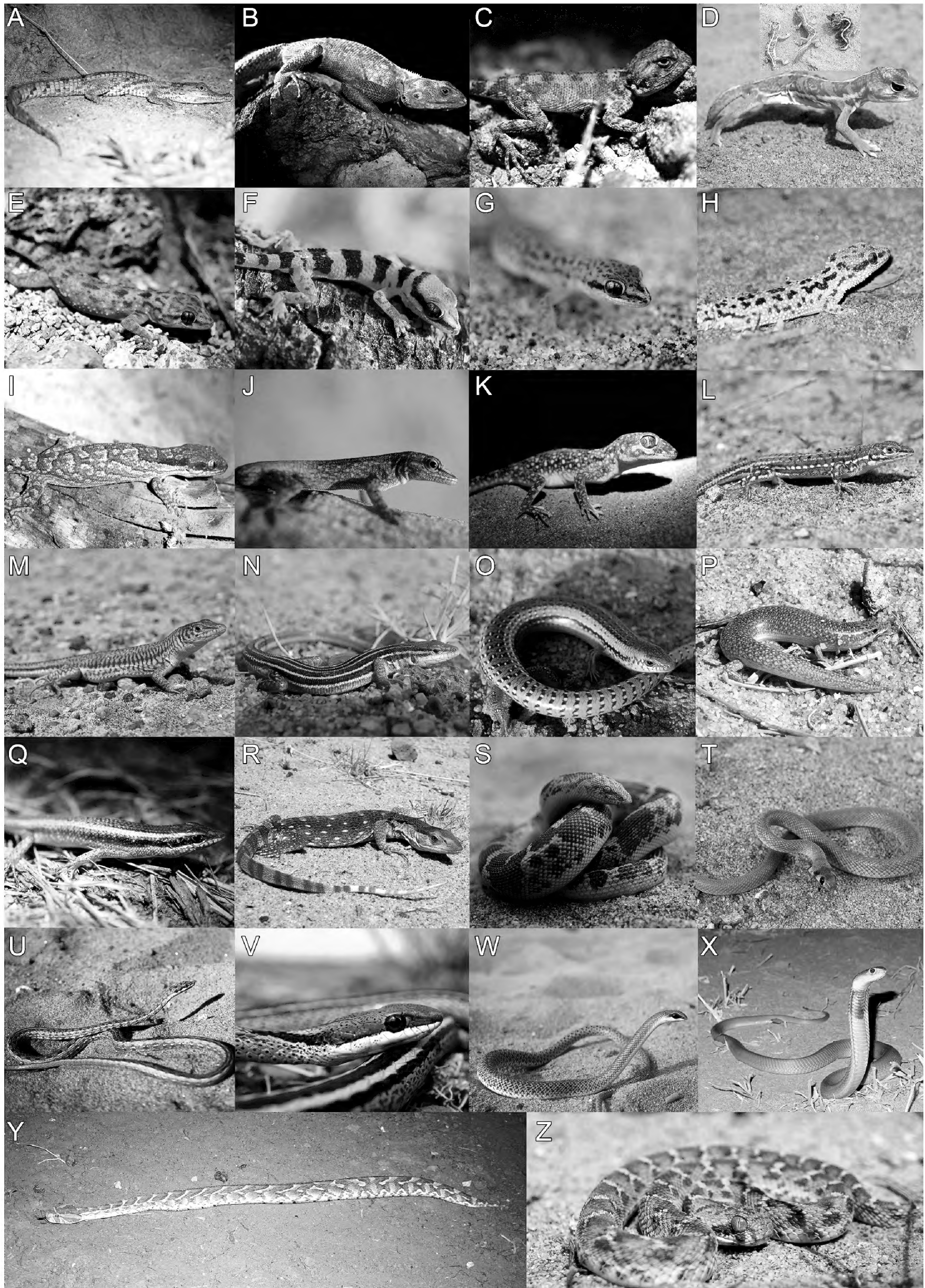
#### *Hemidactylus barbierii* Sindaco, Razzetti, and Ziliani, 2007

Vouchers: NMK-378L/1–4 (field nos. SK16 1078, SK16 1085–1087)

Distribution: KA (R)

Remarks: Four individuals were found at KA (about 15 km inland of Lake Turkana) at about 514 m elevation. These represent the first records from the eastern side of Lake Turkana (Sindaco et al. 2007). This species can be distinguished from the syntopic *Hemidactylus ruspolii* Boulenger, 1896 by the presence of precloacal pores in males (instead of femoral pores), and a dorsal pattern consisting of four transverse dark grey (or at least bordered with dark grey margins) bands (one nuchal and three between anterior and posterior limbs), and a dark rather narrow crescent shaped band bordering the posterior skull margins and extending through the eyes to the nostril (more pronounced in the yellow and black juveniles; Fig 4F). It is different from *Hemidactylus bavazzanoi* Lanza, 1978 in the mental scale arrangement as well as the dorsal pattern, which in *H. bavazzanoi* comprises only three dark transverse bands and a broader crescent shaped head band. Little is known about the ecology of *H. barbierii*. It is usually considered to be terrestrial, hiding under ground coverings or in holes (Sindaco et al. 2007; Spawls et al. 2018). Based on our observations, we consider it to be arboreal rather than terrestrial. This species inhabits the riparian woodlands along dry laggas where individuals were found actively foraging at night on the tree stems and at the bases of trees. All individuals escaped by fleeing up the trees rather than running away on the ground. One recently hatched individual (Fig. 4F) was found during the day hiding under the bark of a *Vachellia* sp. tree at about 1.8 m above the ground on 29 November 2019.





**Fig. 4.** Reptile species recorded during the surveys: (A) *Crocodylus niloticus*; (B) *Agama lionotus*; (C) *Agama rueppelli*; (D) *Holodactylus africanus*; (E) *Hemidactylus angulatus*; (F) *Hemidactylus barbierii*; (G) *Hemidactylus lanzai*; (H) *Hemidactylus ruspolii*; (I) *Homopholis fasciata*; (J) *Lygodactylus somalicus*; (K) *Stenodactylus sthenodactylus*; (L) *Heliobolus spekii*; (M) *Latastia longicaudata*; (N) *Philochortus rudolfensis*; (O) *Chalcides bottegi*; (P) *Mochlus sundevallii*; (Q) *Trachylepis striata*; (R) *Varanus albigularis*; (S) *Eryx colubrinus*; (T) *Platycephalus brevis*; (U) *Psammophis* cf. *tangericus*; (V) *Psammophis punctulatus*; (W) *Rhamphiophis rostratus*; (X) *Naja pallida*; (Y) *Bitis arietans*; and (Z) *Echis pyramidum*.



So far, this species is only known from the Lake Turkana region. The type series was collected south of KF, 10 km inland from AB (Sindaco et al. 2007).

#### Lanza's Gecko

***Hemidactylus lanzai* Šmíd, Mazuch, Nováková, Modrý, Malonza, Elmi, Carranza, and Moravec, 2020 et al. 2020**

Vouchers: NMK-391L (field no. SK16 1021); NMK-383L/1–2 (field nos. SK16 1029, SK16 1033); NMK-395L (field no. SK16 1039); NMK-392L (field no. SK16 1053); NMK-393L (field no. SK16 1037)

Additional tissue samples: SK105 2016

Localities: AB (R), IL (R, G, B), KA (R, B), KF (R, G), LO (R)

Remarks: Recently elevated to a full species from the synonymy of its sister species *Hemidactylus isolepis* Boulenger, 1895, this small, terrestrial gecko is a typical inhabitant of the dry, semi-desert areas in northern Kenya (Spawls et al. 2018). This species (Fig. 4G) was one of the most common reptiles in SNP, with 96 individuals recorded. The highest abundance was along the shores of Lake Turkana, where individuals were hiding in the root system under dried reeds, but it also was found in dry laggas and bushland under dead logs, trees, and rocks. It was exclusively active at night, foraging on sand, gravel, and compact soils. The average  $T_b$  was  $34.0 \pm 1.5$  °C ( $30.5$ – $35.8$  °C;  $N = 10$ ) with  $T_{sub}$  ranging from  $24$ – $47$  °C and  $T_a$  ranging from  $28$ – $38$  °C.

#### Prince Ruspoli's Gecko

***Hemidactylus ruspolii* Boulenger, 1896**

Vouchers: NMK-377L/1–11 (field nos. SK16 1026, SK16 1028, SK16 1032, SK16 1040, SK16 1044, SK16 1054, SK16 1073, SK16 1089)

Localities: AB (R), IL (B, R), KA, (B, R), KF (B, R)

Remarks: This medium-sized gecko (Fig. 4H) is less widespread in East Africa and inhabits drier and lower areas in Kenya, Somalia, and Ethiopia compared to its relative *H. angulatus*. This species was quite abundant in the riverbeds of SNP where we often found it at night under bark, foraging along tree stems, and at the foot of trees. A few individuals were also found in bushland on *Salvadora persica* (“toothbrush tree”). Average  $T_b$  was  $32.3 \pm 1.0$  °C ( $30.5$ – $34.1$  °C;  $N = 12$ ) with  $T_{sub}$  ranging from  $25$ – $33$  °C and  $T_a$  ranging from  $29$ – $34$  °C.

#### Banded Velvet Gecko

***Homopholis fasciata* (Boulenger, 1890)**

Vouchers: NMK-386L/1–2 (field nos. SK16 1095, SK16 1103)

Localities: AB (R), IL (R), KA (B), LO (R)

Remarks: The strictly arboreal Banded Velvet Gecko (Fig. 4I) is a savanna species that typically occupies holes and crevices in large trees from sea level to at least 1,300 m (Spawls et al. 2018). In SNP, we found six individuals in December, March, and April. Individuals were found under bark and in holes of *Vachellia* sp., as well as on the much smaller and bush-like *Salvadora persica*. A gravid female was collected on 30 March 2017. The average  $T_b$  was  $35 \pm 0$  °C ( $N = 2$ ) with  $T_{sub}$  ranging from  $33$ – $34$  °C and  $T_a$  ranging from  $34$ – $35$  °C. These are the first Kenyan records from the eastern side of Lake Turkana.

#### Somali Dwarf Gecko

***Lygodactylus somalicus* Loveridge, 1935**

Vouchers: NMK-387L/1–3 (field nos. SK16 1072, SK16 1101, SK16 1104)

Additional tissue samples: SK278 2016

Localities: IL (R, B), KF (R)

Remarks: This arboreal species is a typical inhabitant of dry savannas and semi-deserts. During our surveys, 39 individuals of this small diurnal gecko (Fig. 4J) were recorded in IL ( $N = 35$ ) and KF ( $N = 4$ ), in both bushland and in dry riverbeds on small trees and shrubs (the majority on *Salvadora persica*, but also on *Vachellia* sp.).

#### Elegant Gecko

***Stenodactylus sthenodactylus* (Lichtenstein, 1823)**

Vouchers: NMK-396L/1–3 (field nos. SK16 1022, SK16 1030, SK16 1031)

Additional tissue samples: SK084 2016, SK120 2016, SK117 2016

Localities: AB (R, B), IL (R, B, G), KA (B), KF (R, B, G), LO (B)

Remarks: This widespread nocturnal, terrestrial gecko (Fig. 4K) is known from semi-deserts and deserts across its range, but in Kenya it has only been recorded in the Lake Turkana vicinity. It was very common in the study area, with 75 individuals recorded. All individuals were found on the ground (sand, gravel, often under shrubs) in the evening and at night (1900 h to 2300 h). The average  $T_b$  was  $32.4 \pm 2.2$  °C ( $25.8$ – $35$  °C;  $N = 20$ ) with  $T_{sub}$  ranging from  $23$ – $33$  °C and  $T_a$  ranging from  $27$ – $35$  °C.

#### Lacertidae

##### Speke's Sand Lizard

***Heliobolus spekii* (Günther, 1872)**

Vouchers: NMK-376L/1–3 (field nos. SK16 1076, SK16 1082, SK16 1088)

Additional tissue samples: SK351 2017, SK468 2017, SK469 2017, SK478 2017, SK479 2017

Localities: KA (B, R), LO (B), TBI

Remarks: *Heliobolus spekii* (Fig. 4L) is a widespread generalist species inhabiting coastal thicket and woodland, moist and dry savanna, and semi-desert at elevations from sea level to 1,500 m (Spawls et al. 2018). We found 18 individuals throughout the study period. This species was absent from the sites near the lake shore and from sparsely vegetated areas. It was only found further inland at the Karare site, Lomosia, and at TBI in more densely vegetated, grassy bushland and on vegetated riverbanks. One pair was observed mating on 17 April 2017. The average  $T_b$  was high at  $37.5 \pm 1.4$  °C ( $34.5$ – $39$  °C;  $N = 8$ ) at substrate temperatures ( $T_{sub}$ ) ranging from  $28$ – $49$  °C and  $T_a$  ranging from  $29$ – $34$  °C.

##### Long-tailed Sand Lizard

***Latastia longicaudata* Reuss, 1834**

Vouchers: NMK-388L (field no. SK16 1027); NMK-385L (field no. SK1034); NMK-384L (field no. SK1050)

Additional tissue samples: SK110.1 2016, SK142 2016, SK158 2016, SK195 2016, SK233 2016, SK295 2017, SK303 2017, SK305 2017, SK306 2017, SK352 2017, SK481 2017



Localities: AB (R, B, G), IL (R, B, G), KA (R, B), KF (R, B), LO (R, B)

Remarks: We recorded 33 individuals of this common diurnal lacertid (Fig. 4M) throughout the study period on all transects between 0800 h and 1930 h. All lizards were darting between bushes in search of prey and places for hiding. Average  $T_b$  was high at  $37.8 \pm 1.2$  °C ( $36.2$ – $39.5$  °C;  $N = 8$ ) at  $T_{sub}$  ranging from  $31$ – $65$  °C and  $T_a$  ranging from  $33$ – $39$  °C. The genus *Latastia* consists of multiple similar-looking species and subspecies, and in some cases, only the suspected distribution range allows for identification. Rigorous genetic analysis is necessary to update the taxonomic status, the distinguishing morphological character traits, and the distribution ranges of existing specimens.

### **Turkana Shield-backed Ground Lizard**

#### ***Philochortus rudolfensis* Parker, 1932**

Vouchers: NMK-382L/1–2 (field nos. SK16 1048, SK89 2016)

Localities: AB (B)

Remarks: Only a limited number of records exist for this species, and its exact range is therefore unknown – it is currently known from southern Ethiopia and northern and central Kenya, at elevations below 800 m (Spawls et al. 2018). During our survey, we found two individuals (Fig. 4N) in a very dry and overgrazed area of the AB bushland on compacted but not rocky substrate in the late mornings of 15 and 16 November 2016. On the same transect, *Agama rueppelli*, *Latastia longicaudata*, *Rhamphiophis rostratus*, *Stenodactylus sthenodactylus*, and *Trachylepis striata* were also recorded.

## **Scincidae**

### **Ocellated Skink**

#### ***Chalcides bottegi* Boulenger, 1898**

Vouchers: NMK-389L (field no. SK16 1092)

Localities: KA (B), KF (G)

Remarks: This skink (Fig. 4O) is known from dry savanna and semi-desert in northern Kenya. We found only two individuals of this semi-fossorial skink in KA and KF in grassland and bushland, respectively. Both individuals were active during the day, one was found under dead reeds along the lake shore, and the other was digging into the loose sand under a *Commiphora africana* shrub. The body temperature of the individual under the reed was  $34.9$  °C at a substrate temperature of  $34$  °C ( $T_a$   $37.5$  °C). These are the first Kenyan records from the eastern side of Lake Turkana.

### **Sundevall's Writhing Skink**

#### ***Mochlus sundevallii* (Smith, 1849)**

Vouchers: NMK-397L/1–4 (field nos. SK16 1035, SK16 1077, SK16 1090, SK16 1106)

Additional tissue samples: SK281 2016

Localities: IL (B, R), KA (R), KF (R, B, G), LO (B)

Remarks: A nocturnal, fossorial species that occupies a variety of habitats comprising coastal savanna and woodland, dry and moist savanna, semi-desert, and medium to high-elevation woodland up to 2,000 m (Spawls et al. 2018). Seventeen individuals of *Mochlus*

*sundevallii* (Fig. 4P) were found, all after sunset, digging in soft sand under shrubs. Average  $T_b$  was  $33.9 \pm 1.0$  °C ( $32.7$ – $34.9$  °C;  $N = 4$ ) at  $T_{sub}$  ranging from  $29$ – $30$  °C and  $T_a$  ranged from  $32$ – $35$  °C.

## **Striped Skink**

#### ***Trachylepis striata* (Peters, 1844)**

Vouchers: NMK-379L/1–5 (field nos. SK16 1036, SK16 1041, SK16 1052, SK16 1069, SK16 1107)

Localities: AB (B, L), IL (B), KA (B), KF (G)

Remarks: A recent study found *Trachylepis striata* (Fig. 4Q) to be paraphyletic, with Ethiopian individuals being the sister group to Tanzanian individuals and *T. mlanjensis* (Loveridge, 1953) from Malawi (Weinell et al. 2019). Kenyan specimens were not included in that study. Extensive molecular analyses of individuals covering the distribution ranges of these taxa will be necessary to resolve their respective status. For now, *Trachylepis striata* is considered a generalist skink, living in forest clearings, coastal thicket, moist and dry savanna, semi-desert, and urban areas (Spawls et al. 2018).

The 14 individuals of a diurnal skink found during this study were assigned to *T. striata* sensu lato. All individuals were discovered on the ground, although this species has been referred to as arboreal (Spawls et al. 2018). The majority of individuals were found under clumps of dead reeds along the lake shore. Average  $T_b$  was  $34.7 \pm 0.4$  °C ( $34.4$ – $35$  °C;  $N = 2$ ) at  $T_{sub}$  ranging from  $34$ – $40$  °C and  $T_a$  was  $34$  °C.

## **Varanidae**

### **Savannah Monitor**

#### ***Varanus albigularis* Daudin, 1802**

CITES App. II

Vouchers: NMK-381L (field no. SK16 1108)

Localities: IL (R), AB (R)

Remarks: This monitor lizard is quite widespread across Africa and occupies different habitats from dry and moist savanna, coastal thicket and woodland, and semi-desert, from sea level to 1,500 m elevation (Spawls et al. 2018). It likely occurs across most of Kenya, but museum specimens are scarce. The records of the rock or White-Throated Monitor represent the first records for the eastern shore of Lake Turkana, although there was hardly any doubt the species occurred there. Three individuals were found in December and April, comprising one adult and two juveniles. The two juveniles (Fig. 4R) were found at night sleeping on tree branches, one was exposed just lying atop the branch at 2 m height, and one was hidden under bark close to the ground. The adult individual was found in the morning under the bark of a tree stem.

### **Nile Monitor**

#### ***Varanus niloticus* (Linnaeus, 1766)**

CITES App. II

Vouchers: None

Localities: IL (G)

Remarks: The most widespread African lizard usually lives near fresh water sources from sea level to around 1,600 m elevation, and rarely higher. We observed one individual Nile Monitor walking along the shore of Lake

Turkana in the early afternoon in December 2016. This species might be under threat in some parts of Africa, as it is exploited for its skin, particularly in West Africa, but the proliferation of dams has provided extra habitat for this species (Spawls et al. 2018). It is probably quite common in SNP.

## Serpentes

### Boidae

#### Kenya Sand Boa

*Eryx colubrinus* (Linnaeus, 1758)

CITES App. II

Vouchers: NMK-372S (field no. SK16 1023)

Additional tissue samples: SK353 2017

Localities: AB (B), IL (B, R), KF (B), LO (B), TBI

Remarks: A typical inhabitant of arid and semi-arid areas in north-eastern Africa (Spawls et al. 2018). The natural history of the Sand Boa (Fig. 4S) is poorly known due to its secretive fossorial lifestyle. We recorded seven individuals. Six of them were active at night or at least after sunset, and the other one recorded during daytime was found at TBI at noon after rain. It was a large female that was lying under a tree in the moist soil with its head buried underground and its entire body exposed; however, it was largely protected from direct sun by the shadow of the tree. Individuals were recorded in November, March, and April mainly in bushland, and only one individual was found in a dry riverbed.

### Colubridae

#### Smith's Racer

*Platyceps brevis* (Boulenger, 1895)

Vouchers: NMK-373S (field no. SK16 1049)

Localities: AB (house wall)

Remarks: This racer occupies dry savanna and semi-desert at elevations spanning 100–1,300 m (Spawls et al. 2018). In the early afternoon (1400 h) of 16 November 2016, we collected a specimen of this species (Fig. 4T) coming out of a crevice in the wall of one of the buildings in the Alia Bay grasslands. Only limited information is known about this species and records are still sparse, leading to a fragmented currently-known distribution range (Spawls et al. 2018).

### Psammophiidae

#### Tanganyika Sand Snake

*Psammophis* cf. *tanganicus* Loveridge, 1940

Vouchers: NMK-370S (field no. SK16 1093)

Records: KA (B)

Remarks: A slim grey sand snake very similar to *Psammophis biseriatus*, of which it was originally described as a subspecies. Its taxonomic status will remain unresolved without thorough genetic and morphological analyses covering their entire ranges. According to Loveridge (1940) the only character separating *P. biseriatus biseriatus* from *P. b. tanganicus* [sic] is the number of labial scales entering the orbit (two in *P. b. biseriatus* vs. three in *P. b. tanganicus* [sic]). Specimen NMK-370S has nine labials and the 4<sup>th</sup>, 5<sup>th</sup>, and 6<sup>th</sup> are

in contact with the orbit. Labials are not plain white but rather largely blotched in light brown. This poorly known snake occurs from sea level to about 1,300 m in dry savanna and semi-desert, but the known Kenyan records are few and very scattered (Spawls et al. 2018). We found only one individual (Fig. 4U) in the bushland at Karare in the evening of 2 December 2016 right at sunset. It was actively moving on the ground, but immediately climbed into a shrub when disturbed. If the specimen proves to be *P. tanganicus* this will be the first record from the Lake Turkana area. Genetic analyses are necessary to resolve the taxonomic status of *P. biseriatus* and *P. tanganicus*.

#### Speckled Sand Snake

*Psammophis punctulatus* Duméril, Bibron, and Duméril, 1854

Vouchers: NMK-S4604 (field no. SK1113)

Records: AB (R), KF (museum headquarters)

Remarks: This common diurnal snake is widely distributed. We found one adult and one juvenile individual in Koobi Fora and Alia Bay in the vegetation along the riverbed and in the Koobi Fora camp, both in April. The large adult individual (Fig. 4V) was feeding on a weaver bird when found (Kirchhof et al. 2018). The currently accepted subspecies *P. p. punctulatus* and *P. p. trivirgatus* (to which the SNP specimens were assigned) seem to be parapatric and morphologically distinguishable, and they might both prove to be full species in the future.

#### Rufous Beaked Snake

*Rhamphiophis rostratus* Peters, 1854

Vouchers: NMK-368S (field no. SK16 1051)

Localities: AB (B)

Remarks: This diurnal snake inhabits semi-desert, dry and moist savanna, coastal thicket, and woodland up to 1,500 m (Spawls et al. 2018). We recorded this large terrestrial snake only once (Fig. 4W) in bushland at Alia Bay in November 2016 at night.

### Elapidae

#### Red Spitting Cobra

*Naja pallida* Boulenger, 1896

Vouchers: NMK-367S (field no. SK16 1047)

Localities: KA (R), KF (G, R)

Remarks: This spitting cobra is another typical occupant of semi-deserts and dry savannas (Spawls et al. 2018). In November 2016, we found three individuals of the gray-phased *Naja pallida* (Fig. 4X). All were active after sunset at Koobi Fora and Karare. One was found in grassland near the lake shore, and the other two were foraging in dry riverbeds.

### Viperidae

#### Puff Adder

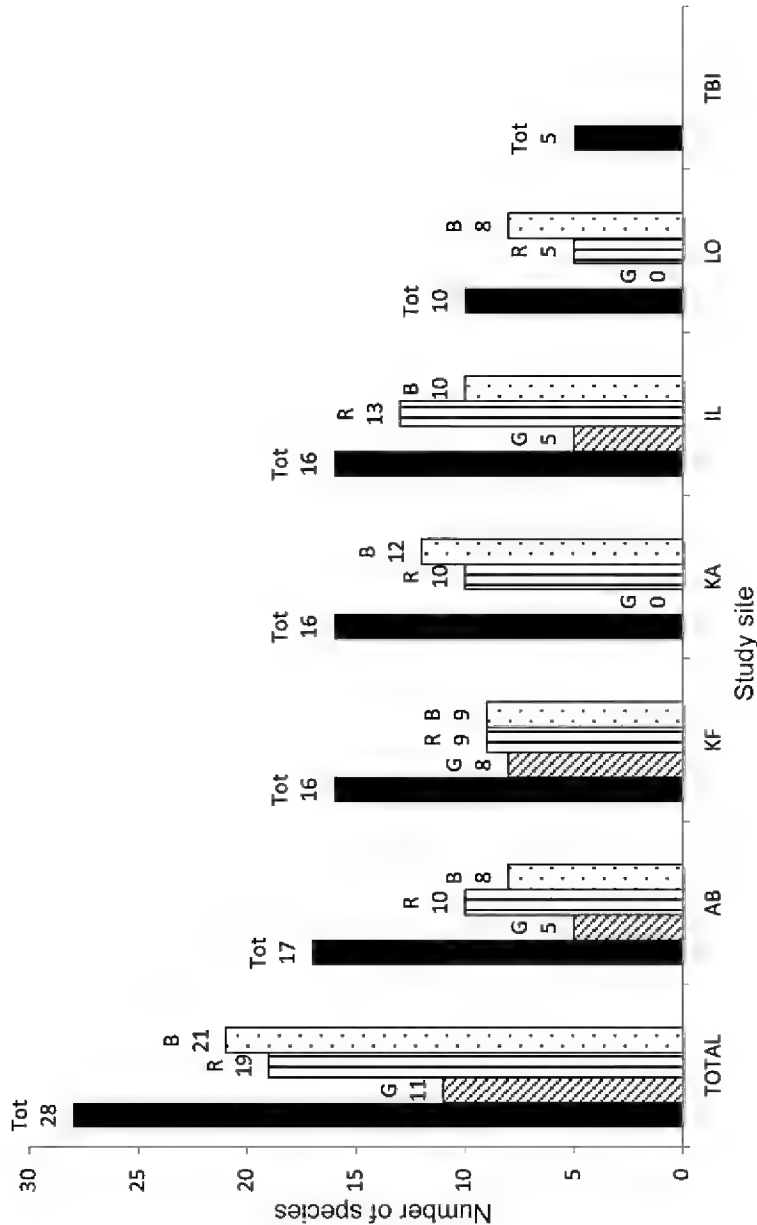
*Bitis arietans* (Merrem, 1820)

Vouchers: NMK-369S (field no. SK16 1102)

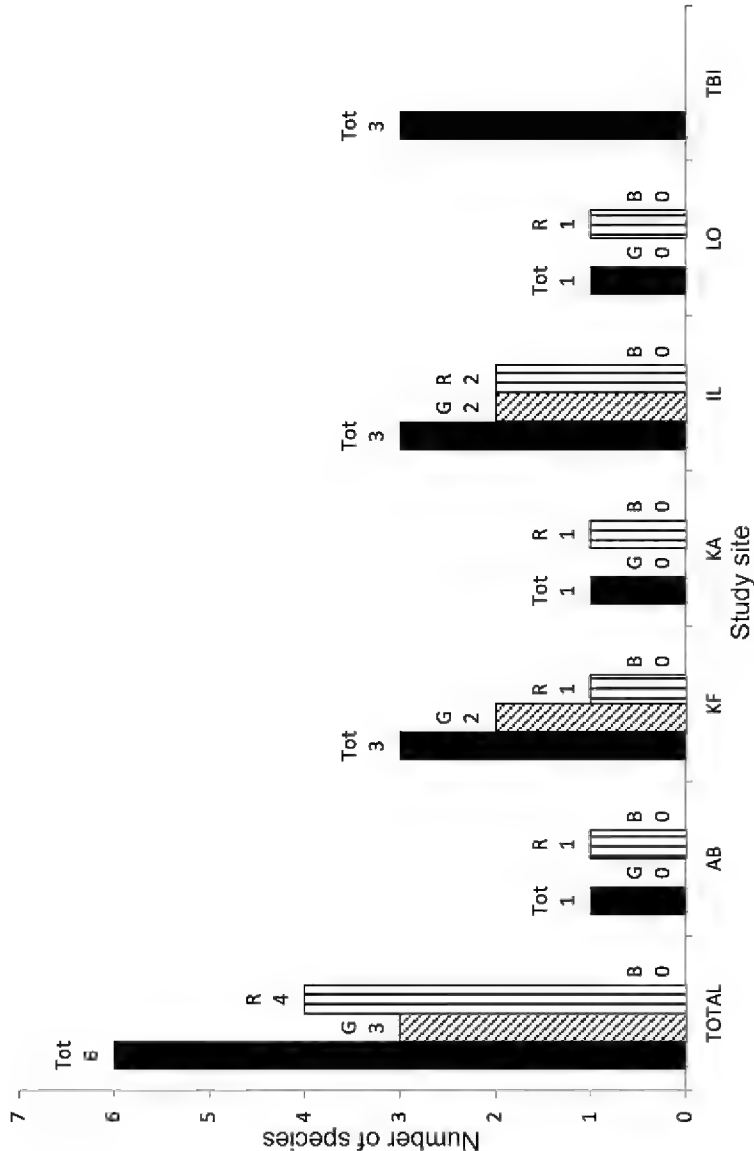
Localities: IL (R)

Remarks: We recorded one individual (Fig. 4Y) of this large and widely distributed viper at night in December 2016 among the *Vachellia* sp. trees in a dry riverbed.

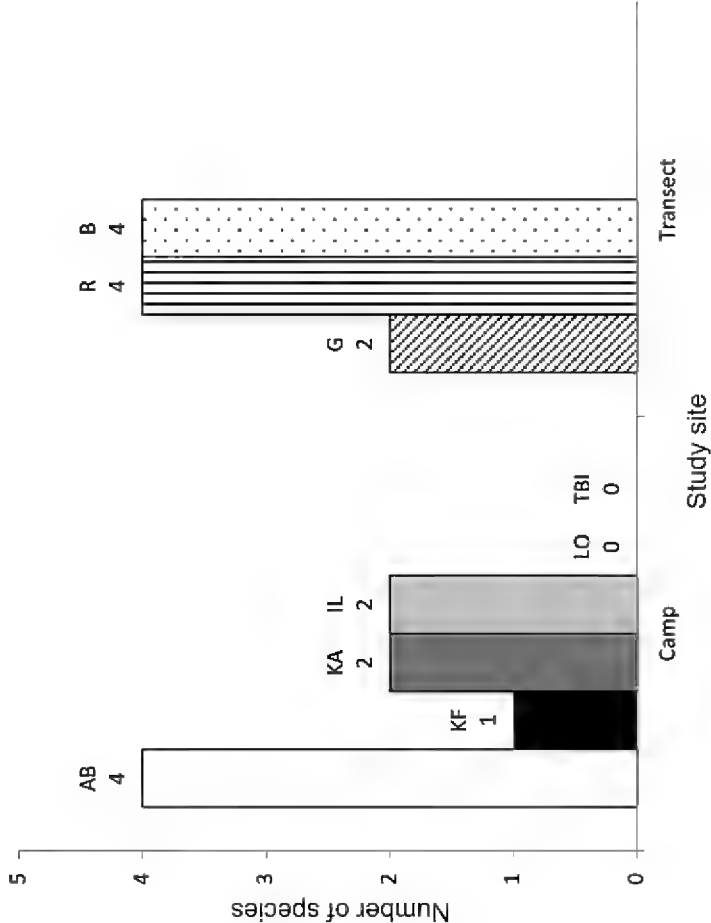




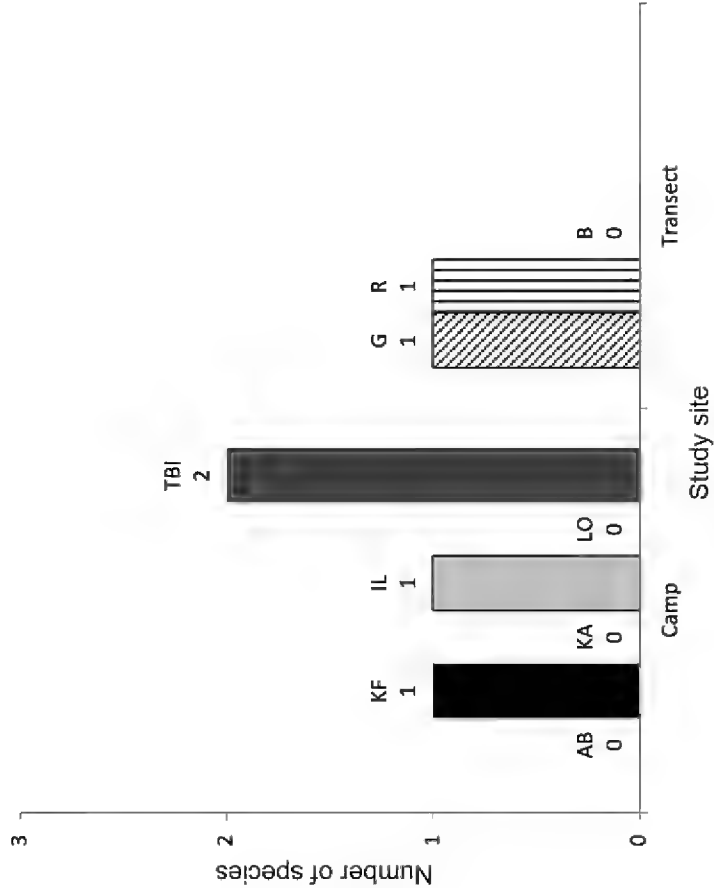
**Fig. 5.** Occurrence of the 28 recorded reptile species across the survey sites (AB, Alia Bay; KF, Koobi Fora; KA, Karare; IL, Ilkemere; LO, Lomosia; TBI, Turkana Basin Institute) and by transect (G, grassland; R, riverbed; B, bushland; Tot, Total).



**Fig. 7.** Occurrence of the six recorded amphibian species across the survey sites (AB, Alia Bay; KF, Koobi Fora; KA, Karare; IL, Ilkemere; LO, Lomosia) and transects (G, grassland; R, riverbed; B, bushland; Tot, Total).



**Fig. 6.** Numbers of reptile species that were exclusively found at either one of the surveyed sites or one of the transects. Abbreviations: AB, Alia Bay; KF, Koobi Fora; KA, Karare; IL, Ilkemere; LO, Lomosia; TBI, Turkana Basin Institute; G, grassland; R, riverbed; B, bushland; Tot, Total.



**Fig. 8.** Numbers of amphibian species that were exclusively found at either one of the surveyed sites or one of the transects. Abbreviations: AB, Alia Bay; KF, Koobi Fora; KA, Karare; IL, Ilkemere; LO, Lomosia; G, grassland; R, riverbed; B, bushland; Tot, Total.

## The Herpetofauna of Sibiloi National Park, Kenya

**Table 1.** List of the amphibian and reptile taxa recorded at Sibiloi National Park, and additional sites along the eastern shore of Lake Turkana south to Mount Kulal, during the present study and from Ziliani et al. (2016). The list does not include *Psammophis semivariegatus*, which is listed by Ziliani et al. (2006), as this taxon does not exist. We assume that this name refers to *Philothamnus semivariegatus* (Smith, 1840) which was listed as *Philothamnus semivariegatus*. We here use the species names as used in Ziliani et al. (2016). Some of these names have undergone taxonomic changes by now, for others we could not find out which taxon was referred to (indicated with (?)), and sometimes the taxon name was misspelled (indicated with [sic]).

	This study	Ziliani et al. (2006)*
<b>AMPHIBIA</b>		
<b>Bufonidae</b>		
<i>Poyntonophrynus lughensis</i> (Loveridge, 1932)	x	<i>Bufo lughensis</i>
<i>Sclerophrys xeros</i> (Tandy, Tandy, Keith, and Duff-MacKay, 1976)	x	–
<i>Sclerophrys turkanae</i> (Tandy and Feener, 1985)	x	<i>Bufo turkanae</i>
<i>Sclerophrys</i> cf. <i>gutturalis</i> (Power, 1927)	–	<i>Bufo</i> cf. <i>gutturalis</i> (Mt. Kulal)
<b>Ptychadenidae</b>		
<i>Ptychadena nilotica</i> (Seetzen, 1855)	x	<i>Ptychadena mascareniensis</i> (?)
<i>Ptychadena anchietae</i> (Bocage, 1868)	–	<i>Ptychadena anchietae</i>
<i>Ptychadena</i> cf. <i>schillukorum</i> (Werner, 1907)	x	–
<i>Ptychadena</i> cf. <i>taenioscelis</i> Laurent, 1954	–	<i>Ptychadena</i> cf. <i>taenioscelis</i>
<b>Pyxicephalidae</b>		
<i>Tomopterna wambensis</i> Wasonga and Channing, 2013	x	<i>Tomopterna cryptotis</i> (?)
<b>REPTILIA</b>		
<b>Pelomedusidae</b>		
<i>Pelomedusa neumanni</i> Petzold, Vargas-Ramírez, Kehlmaier, Vamberger, Branch, Du Preez, Hofmeyr, Meyer, Schleicher, Šíroký, and Fritz, 2014	–	<i>Pelomedusa subrufa</i>
<i>Pelusios broadleyi</i> Bour, 1986	–	<i>Pelusios broadleyi</i>
<b>Testudinidae</b>		
<i>Malacochersus tornieri</i> (Siebenrock, 1903)	–	<i>Malacochersus tornieri</i> (Mt. Kulal)
<b>Trionychidae</b>		
<i>Trionyx triunguis</i> (Forskål, 1775)	x	<i>Trionyx triunguis</i>
<b>Crocodylidae</b>		
<i>Crocodylus niloticus</i> Laurenti, 1768	x	<i>Crocodylus niloticus</i>
<b>Agamidae</b>		
<i>Agama lionotus</i> Boulenger, 1896	x	<i>Agama agama lionotus</i>
<i>Agama rueppelli</i> Vaillant, 1882	x	<i>Agama rueppelli</i>
<b>Chamaeleonidae</b>		
<i>Trioceros bitaeniatus</i> (Fischer, 1884)	–	<i>Chamaeleo bitaeniatus</i> (Mt. Kulal)
<i>Trioceros narraioca</i> (Necas, Modrý, and Šlapeta, 2003)	–	<i>Chamaeleo narraioca</i> [sic] (Mt. Kulal)
<b>Eublepharidae</b>		
<i>Holodactylus africanus</i> Boettger, 1893	x	–
<b>Gekkonidae</b>		
<i>Hemidactylus angulatus</i> Hallowell, 1852	x	<i>Hemidactylus brooki</i> (?)
<i>Hemidactylus barbierii</i> Sindaco, Razzetti, and Ziliani, 2007	x	<i>Hemidactylus</i> n. sp.
<i>Hemidactylus lanzai</i> Šmíd, Mazuch, Nováková, Modrý, Malonza, Elmi, Carranza, and Moravec, 2020	x	<i>Hemidactylus isolepis</i>
<i>Hemidactylus macropholis</i> Boulenger, 1896	–	<i>Hemidactylus macropholis</i>
<i>Hemidactylus platycephalus</i> Peters, 1854	–	<i>Hemidactylus platycephalus</i>



**Table 1 Continued.** List of the amphibian and reptile taxa recorded at Sibiloi National Park, and additional sites along the eastern shore of Lake Turkana south to Mount Kulal, during the present study and from Ziliani et al. (2016). The list does not include *Psammophis semivariegatus*, which is listed by Ziliani et al. (2006), as this taxon does not exist. We assume that this name refers to *Philothamnus semivariegatus* (Smith, 1840) which was listed as *Philothamnus semivariegatus*. We here use the species names as used in Ziliani et al. (2016). Some of these names have undergone taxonomic changes by now, for others we could not find out which taxon was referred to (indicated with (?)), and sometimes the taxon name was misspelled (indicated with [sic]).

	This study	Ziliani et al. (2006)*
<i>Hemidactylus ruspolii</i> Boulenger, 1896	x	<i>Hemidactylus ruspolii</i>
<i>Homopholis fasciata</i> (Boulenger, 1890)	x	—
<i>Lygodactylus keniensis</i> Parker, 1936	—	<i>Lygodactylus keniensis</i> [sic]
<i>Lygodactylus somalicus</i> Loveridge, 1935	x	<i>Lygodactylus</i> cf. <i>somalicus</i>
<i>Stenodactylus sthenodactylus</i> (Lichtenstein, 1823)	x	<i>Stenodactylus sthenodactylus</i>
<b>Gerrhosauridae</b>		
<i>Gerrhosaurus flavigularis</i> Wiegmann, 1828	—	<i>Gerrhosaurus flavigularis</i> (Mt. Kulal)
<b>Lacertidae</b>		
<i>Heliobolus spekii</i> (Günther, 1872)	x	<i>Heliobolus spekii</i>
<i>Latastia longicaudata</i> Reuss, 1834	x	<i>Latastia longicaudata</i>
<i>Philochortus rudolfensis</i> Parker, 1932	x	—
<i>Pseuderemias smithi</i> (Boulenger, 1895)	—	<i>Pseuderemias smithi</i>
<b>Scincidae</b>		
<i>Panaspis</i> sp.	—	<i>Afroblepharus</i> sp.
<i>Chalcides bottegi</i> Boulenger, 1898	x	<i>Chalcides ocellatus bottegi</i>
<i>Mochlus sundevallii</i> (Smith, 1849)	x	<i>Lygosoma sundevalli</i> [sic] and <i>Lygosoma afrum</i> (Mt. Kulal)
<i>Trachylepis quinquetaeniata</i> (Lichtenstein, 1823)	—	<i>Mabuya quinquetaeniata</i>
<i>Trachylepis striata</i> (Peters, 1844)	x	<i>Mabuya striata</i>
<i>Trachylepis varia</i> (Peters, 1867)	—	<i>Mabuya varia</i>
<b>Varanidae</b>		
<i>Varanus albigularis</i> Daudin, 1802.	x	—
<i>Varanus niloticus</i> (Linnaeus, 1766)	x	—
<b>Atractaspididae</b>		
<i>Aparallactus lumulatus</i> (Peters, 1854)	—	<i>Apparalactus lumulatus</i> [sic] (Mt. Kulal)
<b>Boidae</b>		
<i>Eryx colubrinus</i> (Linnaeus, 1758)	x	<i>Eryx colubrinus</i>
<b>Colubridae</b>		
<i>Crotaphopeltis hotamboeia</i> (Laurenti, 1768)	—	<i>Crotaphopeltis hotamboeia</i> (Mt. Kulal)
<i>Dasypeltis scabra</i> (Linnaeus, 1758)	—	<i>Dasypeltis scabra</i> (Mt. Kulal)
<i>Dispholidus typus</i> (Smith, 1829)	—	<i>Dispholidus typus</i> (Mt. Kulal)
<i>Philothamnus semivariegatus</i> (Smith, 1840)	—	<i>Philothamnus semivariegatus</i> [sic] (Mt. Kulal)
<i>Platycephalus brevis</i> (Boulenger, 1895)	x	<i>Platycephalus brevis smithi</i>
<i>Platycephalus florulentus</i> (Geoffroy Saint-Hilaire, 1827)	—	<i>Platycephalus florulentus florulentus</i>
<i>Telescopus obtusus</i> (Reuss, 1834)	—	<i>Telescopus dhara</i>
<b>Elapidae</b>		
<i>Naja haje</i> (Linnaeus, 1758)	—	<i>Naja haje</i> [sic] (Mt. Kulal)
<i>Naja pallida</i> Boulenger, 1896	x	<i>Naja pallida</i>

**Table 1 Continued.** List of the amphibian and reptile taxa recorded at Sibiloi National Park, and additional sites along the eastern shore of Lake Turkana south to Mount Kulal, during the present study and from Ziliani et al. (2016). The list does not include *Psammophis semivariegatus*, which is listed by Ziliani et al. (2006), as this taxon does not exist. We assume that this name refers to *Philothamnus semivariegatus* (Smith, 1840) which was listed as *Philothamnus semivariegatus*. We here use the species names as used in Ziliani et al. (2016). Some of these names have undergone taxonomic changes by now, for others we could not find out which taxon was referred to (indicated with (?)), and sometimes the taxon name was misspelled (indicated with [sic]).

	This study	Ziliani et al. (2006)*
<b>Lamprophiidae</b>		
<i>Boaedon fuliginosus</i> (Boie, 1827)	–	<i>Lamprophis fuliginosus</i> (Mt. Kulal)
<i>Lycophidion</i> sp.	–	<i>Lycophidion</i> sp. (Mt. Kulal)
<b>Leptotyphlopidae</b>		
<i>Myriopholis macrorhyncha</i> (Jan, 1860)	–	<i>Leptotyphlops machrorhynchus</i>
<b>Psammophiidae</b>		
<i>Psammophis biseriatus</i> (Peters, 1881)	–	<i>Psammophis biseriatus</i> (Mt. Kulal)
<i>Psammophis punctulatus</i> Duméril, Bibron, and Duméril, 1854	x	<i>Psammophis</i> cf. <i>punctulatus</i>
<i>Psammophis</i> cf. <i>tanganicus</i> Loveridge, 1940	x	–
<i>Rhamphiophis rostratus</i> Peters, 1854	x	–
<i>Rhamphiophis rubropunctatus</i> (Fischer, 1884)		<i>Rhamphiophis rubropunctatus</i>
<b>Viperidae</b>		
<i>Bitis arietans</i> (Merrem, 1820)	x	<i>Bitis arietans</i>
<i>Echis pyramidum</i> (Geoffroy Saint-Hilaire, 1827)	x	<i>Echis pyramidum</i>

North-east African Carpet Viper

*Echis pyramidum* (Geoffroy Saint-Hilaire, 1827)

Vouchers: NMK-374S (field no. SK16 1025); NMK-371S (field no. SK16 1149)

Additional tissue samples: SK051 2016

Localities: AB (B, R), IL (B, R), KA (B), KF (B, G, R), LO (R)

Remarks: The most common snake in SNP during our expeditions was *Echis pyramidum*, with 38 individuals recorded. This species (Fig. 4Z) occurred at all our study sites and in all transect types, but with a predilection for bushland (26 records). Activity was restricted to the night time, and records during daytime were exclusively of resting individuals dug out under dead logs.

Camp and Transect Comparisons

Of the 28 reptile species, 11 were recorded in the grasslands along the lake shore (of those, *P. brevis* was not recorded in natural habitat but on the wall of a building), 19 in the dry riverbeds, and 21 in bushland. The species diversity of the different sites were very similar (16–17 species per site) when the sites with similar collecting effort were compared, i.e., Lomosia with 10 species was only surveyed in March–April 2017, and species at TBI were recorded opportunistically (Fig. 5). The species found only at one site comprised four at Alia Bay (*Agama lionotus*, *Philochortus rudolfensis*, *Platyceps brevis*, *Rhamphiophis rostratus*), one species at Koobi Fora (*Trionyx triunguis*), two species at Karare (*Hemidactylus barbierii*, *Psammophis* cf. *tanganicus*), and two at Ilkemere (*Bitis arietans*, *Varanus niloticus*) (Fig. 6). *Philochortus rudolfensis*, *P.*

cf. *tanganicus*, and *R. rostratus* (and the *Trionyx triunguis* carapace) were found only on bushland transects; *A. lionotus*, *B. arietans*, *Hemidactylus barbierii*, and *Varanus albigularis* occurred exclusively in dry riverbeds; and *P. brevis* and *V. niloticus* were only found in the grassland transects at Ilkemere and Alia Bay, respectively (Fig. 6).

Most of the six species of amphibians (four species; *Ptychadena nilotica*, *Ptychadena* cf. *schillukorum*, *Sclerophrys turkanae*, and *Tomopterna wambensis*; Fig. 7) were found in the dry riverbeds, especially after rains. Three amphibian species were recorded in grasslands. Of those, *P. nilotica* and *S. turkanae* were found in the highly alkaline (pH = 9.2) and saline (TDS = 2,500 ppm; Yuretich and Cerling 1983) water of Lake Turkana. The fossorial *T. wambensis* either appeared from out of its underground hiding place away from the waters after rain, or it was calling at sites away from the lake at the edges of confined water bodies, which were most probably fed mainly by the high levels of groundwater and rain water. Of the three species recorded at TBI, *T. wambensis* and *Poyntonophrynus lughensis* were mating in a freshly flooded temporary waterbody after heavy rains in bushland, while *Sclerophrys xeros* was sitting in the artificial water reservoir of the station. Only a single individual of *P.* cf. *schillukorum* was found in a dry riverbed at Ilkemere (Fig. 8).

Discussion

The results of two herpetological surveys in the SNP along parts of the eastern shore of Lake Turkana in northern Kenya are presented here. In addition to the records of 28 reptiles and six amphibians from these surveys, a



checklist of the herpetofauna in an extended area east of Lake Turkana from the Ethiopian border in the north, east to the town of North Horr, and south to Mount Kulal was presented at the 6<sup>th</sup> Congresso Nazionale della Societas Herpetologica Italica in Rome, Italy in 2006 (Ziliani et al. 2006). Our surveys added seven species of reptiles and two amphibians that were not found during the 10 herpetological surveys conducted by Ziliani et al. (2006), despite their coverage of a larger range and spending more time. These nine species are: *Holodactylus africanus*, *Homopholis fasciata*, *Philochortus rudolfensis*, *Psammophis* cf. *tanganicus*, *Ptychadena* cf. *schillukorum*, *Rhamphiophis rostratus*, *Sclerophrys xeros*, *Varanus albigularis*, and *Varanus niloticus*. Thirteen reptile species and two amphibians recorded by Ziliani et al. (2006) in xeric habitats were not detected in our surveys. Most likely these taxa also find suitable habitat in SNP and are expected to occur there (Table 1). We did not consider the species that were recorded by Ziliani et al. (2006) in the very ecologically different, more mesic vegetation types, including the afro-montane forest remnants at Mount Kulal (14 species, excluding *Lygosoma afrum*, currently considered a synonym of *M. sundevallii* and *Psammophis semivariegatus*, which does not exist and is likely *Philothamnus semivariegatus*; Table 1).

Among the unique environmental features of the area for the local herpetofauna are (i) Lake Turkana, a permanent water source in this semi-desert, with a high pH and high salinity (for aquatic animals) and (ii) the terrestrial shoreline of the lake with localized grass-dominated habitats. Our results show the lowest species diversity in those grasslands, a fact that was unexpected. However, the grasslands seem to be experiencing the highest impact from local livestock overgrazing. In addition, the prolonged droughts in the area likely affect the grasslands through changes in the flooding regime and seasonal lake-level fluctuations. Along the shore, the four species that were not recorded anywhere else can apparently withstand the rather inhospitable chemical conditions of the lake water. Those four species are: *Crocodylus niloticus*, except for one individual that was found a little further inland near one of our bushland transects; *Varanus niloticus*, a monitor lizard that lives close to water; *Platycephalus brevis*, this species is not aquatic and was recorded in anthropogenic habitat between the stones of the wall of a building; and the toad *Sclerophrys turkanae*. Furthermore, although they were not recorded alive during our expeditions, three aquatic species of turtles and terrapins (*Pelusios broadleyi*, *Pelomedusa subrufa* [sic], now *P. neumanni*, and *Trionyx triunguis*) are restricted to the lake (Ziliani et al. 2006). These species are subject to fishing pressure, and they often end up as bycatch, are disturbed by fishermen, become entangled in nets, or take baited fishing hooks and drown (IUCN World Heritage Outlook 2020).

The dry riverbeds also represent an important habitat, especially in such a dry area, mainly due to their high groundwater levels which are mandatory for the trees growing in the narrow riparian woodlands along the river. Consequently, we found most of the amphibian species in the riverbeds (*Ptychadena nilotica*,

*Ptychadena* cf. *schillukorum*, *Sclerophrys turkanae*, and *Tomopterna wambensis*), as well as the more or less arboreal reptile species (*Agama lionotus*, *Hemidactylus barbieri*, *Hemidactylus ruspolii*, *Homopholis fasciata*, and *Lygodactylus somalicus*), although many of the latter also inhabited the shrubs in the bushland. Furthermore, the three individuals of *Varanus albigularis* were found exclusively along the riverbeds under loose bark of trees. The number of individuals we recorded is not a completely accurate representation of abundance because not every individual encountered was caught and marked. As a result, on each second surveying day per transect there was a possibility of re-recording of individuals.

In addition to the aforementioned aquatic and arboreal species, the recorded herpetofauna of the SNP comprises species typical of the semi-arid to arid savannas of East Africa. A few of the species, such as *Bitis arietans*, *Heliobolus spekii*, *Hemidactylus platycephalus*, *Homopholis fasciata*, *Mochlus sundevallii*, *Rhamphiophis rostratus*, *R. rubropunctatus*, *Trachylepis quinquetaeniata*, *T. striata*, *T. varia*, and *Varanus albigularis*, are widespread and generalist, also inhabiting moist and dry savanna areas. These species are generally distributed further to the south and enter parts of Central Africa. Furthermore, a few Palearctic taxa reach the Turkana area, such as *Echis pyramidum* and *Stenodactylus sthenodactylus*, as well as the largely Palearctic genus *Eryx* which is represented in SNP by *E. colubrinus*.

## Environmental Changes over Recent Decades

Recently, the area around SNP has received more attention from biologists and conservationists than in the past (e.g., Cabeza et al. 2016; Conenna et al. 2019; Junqueira et al. 2021; Torrents-Ticó et al. 2021). The overall outcomes and impressions of these various studies are that throughout the past decades, the xeric areas in northern Kenya, including Lake Turkana and SNP, have been facing severe anthropogenic pressures. A 2 °C rise in minimum and maximum temperatures between 1967 and 2012 in the Turkana area has been reported (Avery 2012), as well as changes in the intensity and frequency of rainy seasons and increased duration and frequency of severe droughts (Junqueira et al. 2021). Ethnographic studies also report that the Daasanach people in the area have perceived increases in temperature and wind strength, drier and less fertile soils, less grass and increased water salinity (Junqueira et al. 2021). Photographic evidence from the 1960s shows that there was once a rich mammalian fauna in SNP, with giraffes, lions, and cheetahs, all of which are now locally extirpated (IUCN World Heritage Outlook 2020), and the local elders reported fertile and green pastures for their livestock in the past (Cabeza et al. 2016). Herders also report changes in the population trends of many of the mammals in the area (Torrents-Ticó et al. 2021). Whether these changes are also affecting the herpetofauna of SNP is less clear, since most reptiles and amphibians are less targeted by the local population than the mammals. Nevertheless, changes in the lake water levels and increased anthropogenic pressures with negative impacts

on the vegetation cover (shade), insect abundance (reptile and amphibian prey), ground water levels, and land use practices (agro-pastoralism, fishing), are likely to have already impacted the diversity and abundance of reptile and amphibian species.

Our results show that the majority of the herpetofauna of the SNP comprises desert and semi-desert taxa. Museum specimens are very rare for the eastern shore of Lake Turkana, which motivated us to collect voucher specimens of the local herpetofauna for the NMK collection to serve as a baseline for future generations of conservationists and biologists. The reptile and amphibian species recorded at Mount Kulal, which is about 100 km south of SNP and covered by afro-montane forest remnants and mesophilous vegetation formations, show a herpetofauna community comprising species that typically occur in mesic savannas and forests further to the south and west, e.g., *Bufo* (*Sclerophrys*) *gutturalis*, *Crotaphopeltis* *hotamboeia*, *Dispholidus* *typus*, *Gerrhosaurus* *flavigularis*, and *Philothamnus* *semivariegatus* [sic] (*Philothamnus* *semivariegatus*) (Ziliani et al. 2006). These species seem to represent relict populations for the area, and they were likely to be more widespread under the less severe environmental conditions which were reportedly still prevalent in the Turkana region less than 50 years ago (Cabeza et al. 2016; Junqueira et al. 2021; Torrents-Ticó et al. 2021). The opportunistically recorded field body temperatures of some of the species (see Species Accounts) were not exceptionally high, so we assume that at least those taxa were able to effectively thermoregulate in the SNP despite the increased environmental temperatures (Avery 2012).

## Conclusions

The SNP harbors a high diversity of reptiles, and also a decent amount of amphibian taxa for a xeric environment, and many of these taxa are poorly studied. During two surveys, a number of species were found for the first time in SNP, although none of them were unexpected based on their known ecology and distribution ranges. There are probably some more species to discover in the area, and splitting taxa based on molecular analyses might further extend the species list. Based on the present survey and the expeditions by Ziliani et al. (2006), the currently known reptile and amphibian fauna of the SNP comprises 49 species, including eight amphibians and 41 reptiles (three freshwater turtles, one crocodile, 25 lizards, and 12 snakes).

The herpetofauna includes species typical of the semi-arid to arid savannas of East Africa (including arboreal taxa), a few taxa with more Palearctic distributions, a few widespread and generalist taxa that also inhabit more humid areas, and the aquatic species dependent on Lake Turkana. The latter group comprises four reptile species listed on CITES App. II and two reptile species listed on the IUCN Red List, highlighting the importance of the lake for the Reptilia. These species are also the most likely group to be affected if the water resources, including the amount of available water and the chemistry of the lake, are negatively impacted by climate change

and the Gilgel Gibe III Dam in Ethiopia. In addition, the habitats associated with the ephemeral rivers that have high groundwater levels and riparian woodlands/forests, which are home to most amphibian species and many reptile species, will be heavily affected if water levels drop. The grassy habitats along the lake shore seem to be impacted by overgrazing and now harbor fewer reptile and amphibian species than expected. Overall, the herpetofauna of this area includes a number of CITES and IUCN Red List listed species, including endemics, that warrant protection and conservation measures to prevent further defaunation.

**Acknowledgments.**—We thank the National Commission for Science, Technology, and Innovation (NACOSTI/P/16/21446/14491) and Kenya Wildlife Service (KWS/BRM/5001) for granting access to the area, and the Turkana Basin Institute (TBI) for all their logistic support. This study has received funding from the Nordenskiöld Expedition fund (granted to Mar Cabeza, University of Helsinki), and funds for the promotion and support of young researchers from the Museum für Naturkunde Berlin (Germany) (granted to Sebastian Kirchhof). The authors wish to thank Mikael Fortelius and Mar Cabeza (both at University of Helsinki) for offering the opportunity to join the two expeditions to SNP, and Shooro Claudia Goosh, Lawrence Losogo Bosco, Irene Conenna, the Helsinki team, and the TBI team for their field assistance, team spirit, general help, and company. Mar Cabeza also added helpful comments to the manuscript. Special thanks go to Eli Greenbaum for his suggestions which improved the article.

## Literature Cited

- Avery S. 2012. *Lake Turkana and the Lower Omo: Hydrological Impacts of Major Dam and Irrigation Developments*. Report. African Studies Centre, University of Oxford, Oxford, United Kingdom. 239 p.
- BirdLife International. 2022. Important Bird Areas factsheet: Lake Turkana. Available at: <http://www.birdlife.org> [Accessed: 1 November 2022].
- Cabeza M, Fernandez-Llamazares A, Fraixedas S, López-Baucells A, Burgas D, Rocha R, Ajiko A. 2016. Winds of hope for Sibiloi National Park. *Swara* 4: 33–37.
- Ceríaco L, Marques MP, Bandeira S, Agarwal I, Stanley EL, Bauer AM, Heinicke MP, Blackburn DC. 2018. A new earless species of *Poyntonophrynus* (Anura, Bufonidae) from the Serra da Neve Inselberg, Namibe Province, Angola. *ZooKeys* 780: 109–136.
- Channing A, Howell K. 2006. *Amphibians of East Africa*. Comstock Publishing Associates/Cornell University Press, Ithaca, New York, USA. 418 p. + 24 pl.
- Conenna I, López-Baucells A, Rocha R, Ripperger S, Cabeza M. 2019. Movement seasonality in a desert-dwelling bat revealed by miniature GPS loggers. *Movement Ecology* 7(1): 1–10.
- Cox N, Young BE, Bowles P, Fernandez M, Marin J, Rapacciuolo G, Böhm M, Brooks T, Hedges



- SB, Hilton-Taylor C, et al. 2022. A global reptile assessment highlights shared conservation needs of tetrapods. *Nature* 605(7909): 285–290.
- Frost DR. 2022. Amphibian Species of the World: an Online Reference. Version 6.1. American Museum of Natural History, New York, New York, USA. Available: <https://amphibiansoftheworld.amnh.org/index.php> [Accessed: 1 April 2022].
- IUCN SSC Amphibian Specialist Group. 2016. *Sclerophrys turkanae*. The IUCN Red List of Threatened Species 2016: e.T54784A107351510.
- IUCN World Heritage Outlook. 2020. Lake Turkana National Parks - 2020 Conservation Outlook Assessment. IUCN, Gland, Switzerland. Available: <https://rris.biopama.org/node/20655> [Accessed: 2 November 2022].
- Junqueira AB, Fernández-Llamazares Á, Torrents-Ticó M, Haira PL, Nasak JG, Burgas D, Fraixedas S, Cabeza M, Reyes-García V. 2021. Interactions between climate change and infrastructure projects in changing water resources: an ethnobiological perspective from the Daasanach, Kenya. *Journal of Ethnobiology* 41(3): 331–348.
- Kaijage S, Nyagah N. 2009. *Socio-economic Analysis and Public Consultation of Lake Turkana Communities in Northern Kenya. Final Report*. African Development Bank, Tunis, Tunisia. 191 p.
- Kirchhof S, Losogo LB, Malonza PK. 2018. *Psammophis punctulatus trivirgatus* (Southern Speckled Sand Snake). Diet. *Herpetological Review* 49(3): 552–553.
- Largen MJ, Spawls S. 2010. *The Amphibians and Reptiles of Ethiopia and Eritrea*. Frankfurt Contributions to Natural History, Volume 38. Edition Chimaira, Frankfurt am Main, Germany. 693 p.
- Largen MJ. 2001. Catalogue of the amphibians of Ethiopia, including a key for their identification. *Tropical Zoology* 14(2): 307–402.
- Liedtke HC, Müller H, Hafner J, Penner J, Gower DJ, Mazuch T, Rödel MO, Loader SP. 2017. Terrestrial reproduction as an adaptation to steep terrain in African toads. *Proceedings of the Royal Society B: Biological Sciences* 284(1851): 20162598.
- Loveridge A. 1940. Revision of the African snakes of the genera *Dromophis* and *Psammophis*. *Bulletin of the Museum of Comparative Zoology* 87(1): 1–69.
- Mbaluka JK, Brown FH. 2016. Vegetation of the Koobi Fora Region northeast of Lake Turkana, Marsabit County, northern Kenya. *Journal of East African Natural History* 105(1): 21–50.
- Nago SGA, Grell O, Sinsin B, Rödel MO. 2006. The amphibian fauna of the Pendjari National Park and surroundings, northern Benin. *Salamandra* 42: 93–108.
- Olson DM, Dinerstein E, Wikramanayake ED, Burgess ND, Powell GV, Underwood EC, D'Amico JA, Itoua I, Strand HE, Kassem KR, et al. 2001. Terrestrial ecoregions of the world: a new map of life on Earth. A new global map of terrestrial ecoregions provides an innovative tool for conserving biodiversity. *BioScience* 51: 933–938.
- Sindaco R, Razzetti E, Ziliani U, Wasonga V, Carugati C, Fasola M. 2007. A new species of *Hemidactylus* from Lake Turkana, northern Kenya (Squamata: Gekkonidae). *Acta Herpetologica* 2: 37–48.
- Spawls S, Howell K, Hinkel H, Menegon M. 2018. *Field Guide to East African Reptiles*. Bloomsbury Publishing, London, United Kingdom. 624 p.
- Spawls S, Wasonga V, Drewes RC. 2019. *The Amphibians of Kenya*. Stephen Spawls (privately published). 55 p.
- Tolley KA, Alexander GJ, Branch WR, Bowles P, Maritz B. 2016. Conservation status and threats for African reptiles. *Biological Conservation* 204: 63–71.
- Thorsell J. 2003. *World Heritage Nomination—IUCN Technical Evaluation*. Ilulissat Icefjord (Denmark) ID No: 1149. IUCN, Gland, Switzerland. 5 p.
- Torrents-Ticó M, Fernández-Llamazares A, Burgas D, Cabeza M. 2021. Convergences and divergences between scientific and indigenous and local knowledge contribute to inform carnivore conservation. *Ambio* 50(5): 990–1,002.
- Uetz P, Freed P, Aguilar R, Hošek J. (Editors). 2022. The Reptile Database. Available: <http://www.reptile-database.org> [Accessed: 1 April 2022].
- UNEP-WCMC, IUCN. 2022. Protected Planet: The World Database on Protected Areas (WDPA) and World Database on Other Effective Area-based Conservation Measures (WD-OECM). UNEP-WCMC, Cambridge, United Kingdom and IUCN, Gland, Switzerland. Available: <http://www.protectedplanet.net> [Accessed: 10 July 2022].
- Weinell JL, Branch WR, Colston TJ, Jackman TR, Kuhn A, Conradie W, Bauer AM. 2019. A species-level phylogeny of *Trachylepis* (Scincidae: Mabuyinae) provides insight into their reproductive mode evolution. *Molecular Phylogenetics and Evolution* 136: 183–195.
- Yuretich RF, Cerling TE. 1983. Hydrogeochemistry of Lake Turkana, Kenya: mass balance and mineral reactions in an alkaline lake. *Geochimica et Cosmochimica Acta* 47(6): 1,099–1,109.
- Ziliani U, Sindaco R, Razzetti E, Wasonga V, Modrý D, Necas P, Carugati C, Fasola M. 2006. The Herpetofauna of the Eastern Side of the Lake Turkana (Northern Kenya). Pp. 192–193 In: *Riassunti del 6° Congresso Nazionale della Societas Herpetologica Italica (Roma, 27.IX-1.X.2006)*. Editors, Bologna MA, Capula M, Carpaneto GM, Luiselli L, Marangoni C, Venchi A. Stiligrafica, Rome, Italy. 238 p.

## The Herpetofauna of Sibiloi National Park, Kenya



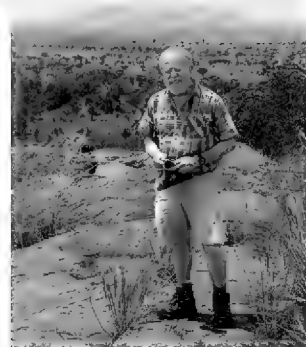
**Sebastian Kirchhof** is a research associate at New York University Abu Dhabi working in close collaboration with the Museum für Naturkunde Berlin, Germany, where he received his Ph.D. Sebastian is a trained ecologist, nature conservationist, and biologist, currently focusing on genomic adaptation to extreme conditions in amphibians and reptiles by combining genomics, transcriptomics, niche modeling, population genomics, and systematics. He is interested in the evolutionary processes responsible for the diversification of Earth's biota and genomic architecture, and how they affect speciation rates. This knowledge is one of the fundamental pillars for the protection of the Earth's biodiversity.



**Victor Wasonga** is a trained conservation biologist and a research scientist based at the National Museums of Kenya. Victor's current research involves using herpetofauna to understand phylogeny, taxonomy, ecology, distribution, landuse, ecosystem dynamics, and livelihoods. He has authored many publications and described a number of species. Victor is currently serving as a Co-Chair of the East African Amphibian Specialist Group within IUCN's Species Survival Commission.



**Tomáš Mazuch** is a Czech amateur herpetologist. Since his teenage years, Tomáš has dedicated his life to the breeding of amphibians, reptiles, and invertebrates. During his studies of Veterinary Sciences (which are not finished yet), he began to devote his research to herpetology and the parasitology of reptiles. His research focuses on the taxonomy, systematics, and biogeography of amphibians and reptiles of the Horn of Africa (mainly Somalia and Ethiopia). His main subjects of study are geckos of the genus *Hemidactylus* from Eastern Africa. Tomáš is also interested in the taxonomy of scorpions and succulent plants from North-Eastern Africa. He has authored or co-authored about 30 peer-reviewed papers and books on parasitology, the systematics of scorpions, plants, and herpetology, including the book *Amphibians and Reptiles of Somaliland and Eastern Ethiopia, Based on Two Field Trips in 2010/2011* in 2013. He has co-authored the descriptions of 11 reptile, six scorpion and two plant species. He currently runs long-term projects and field studies in Somaliland.

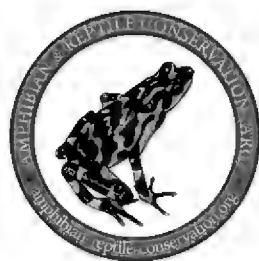


**Stephen Spawls** is an independent herpetologist who has worked extensively in Africa, in Kenya, Egypt, Ghana, Botswana, and Ethiopia. His publications include *A Field Guide to the Reptiles of East Africa* and a book on Africa's dangerous snakes. He lives in Norwich, United Kingdom.



**Patrick Kinyatta Malonza** has been a herpetologist at the National Museums of Kenya-Nairobi since 1996, where he leads a team of other herpetologists and enthusiasts to promote reptile and amphibian conservation in Kenya. Patrick works on the taxonomy, community ecology, and conservation of reptiles and amphibians. He has authored or co-authored over 35 publications. His key interest is understanding species and habitat relationships, species descriptions, and their biogeographical associations.





# Contributions to the herpetofauna of the Angolan Okavango-Cuando-Zambezi river drainages. Part 3: Amphibians

<sup>1,2,3,\*</sup>Werner Conradie, <sup>2,3,4</sup>Chad Keates, <sup>3,5,6</sup>Luke Verburgt, <sup>3,7,8,9,10,11</sup>Ninda L. Baptista,  
and <sup>3,12</sup>James Harvey

<sup>1</sup>Port Elizabeth Museum, Beach Road, Humewood, Port Elizabeth 6013, SOUTH AFRICA <sup>2</sup>Department of Nature Conservation Management, Natural Resource Science and Management Cluster, Faculty of Science, George Campus, Nelson Mandela University, George, SOUTH AFRICA <sup>3</sup>National Geographic Okavango Wilderness Project, Wild Bird Trust, SOUTH AFRICA <sup>4</sup>South African Institute for Aquatic Biodiversity (SAIAB), Makhanda, SOUTH AFRICA <sup>5</sup>Enviro-Insight CC, Unit 8 Oppidraai Office Park, Pretoria 0050, SOUTH AFRICA <sup>6</sup>Department of Zoology and Entomology, University of Pretoria, Pretoria, 0001, SOUTH AFRICA <sup>7</sup>Instituto Superior de Ciências da Educação da Huíla (ISCED), Rua Sarmiento Rodrigues, Lubango, ANGOLA <sup>8</sup>CIBIO/InBio, Centro de Investigação em Biodiversidade e Recursos Genéticos, Laboratório Associado, Universidade do Porto, Campus Agrário de Vairão, Rua Padre Armando Quintas, 4485-661 Vairão, PORTUGAL <sup>9</sup>Departamento de Biologia, Faculdade de Ciências, Universidade do Porto, 4169-007, Porto, PORTUGAL <sup>10</sup>BIOPOLIS Program in Genomics, Biodiversity and Land Planning, CIBIO, Campus de Vairão, 4485-661 Vairão, PORTUGAL <sup>11</sup>Museum für Naturkunde—Leibniz Institute for Evolution and Biodiversity Science, Invalidenstr. 43, 10115 Berlin, GERMANY <sup>12</sup>Harvey Ecological, 41 Devonshire Avenue, Howick, 3290, SOUTH AFRICA

**Abstract.**—This article is the third and final installment of the herpetofaunal results obtained from a series of rapid biodiversity surveys of the upper Cuito, Cubango, Cuando, Zambezi, and Kwanza River basins in Angola. The amphibian survey results are presented along with an updated checklist of the historical and current records of amphibians from the southeastern region of Angola. A total of 1,114 new amphibian records were documented, comprising 37 species, bringing the total number of recognized amphibian species in this region to 49. These surveys documented two new country records (*Hyperolius* cf. *inyangae* and *Kassinula wittei*) and at least two candidate new species, and elevated *Amnirana adiscifera* stat. nov. (which now encompasses the western green form formerly regarded as *A. darlingi*). Finally, updated distribution maps for all of Angola are provided for all the species encountered within the study region.

**Keywords.** Africa, Cuanavale, Cuito, Okavango, headwaters, frogs

**Resumo.**—Este trabalho é a terceira e última parte dos resultados obtidos de uma série de levantamentos rápidos de biodiversidade realizados nas bacias dos rios Cuito, Cubango, Cuando, Zambeze e Kwanza em Angola. Aqui apresentamos uma lista atualizada de registos anfíbios do sudeste de Angola, consistindo em registos históricos e actuais. Ao todo foram obtidos 1,114 novos registos, relativos a 37 espécies, elevando o número total de espécies de anfíbios reconhecidas nesta região para 49. Duas espécies foram registadas no país pela primeira vez (*Hyperolius* cf. *inyangae*, *Kassinula wittei*). Os nossos resultados sugerem a existência de pelo menos duas potenciais espécies novas, e elevaram o estatuto de *Amnirana adiscifera* stat. nov. para abranger a forma verde ocidental de *A. darlingi*. Por fim, produzimos mapas de distribuição actualizados para todas as espécies encontradas neste estudo para o país inteiro.

**Palavras-chave.** África, Cuanavale, Cuito, Okavango, nascentes, sapos

**Citation:** Conradie W, Keates C, Verburgt L, Baptista NL, Harvey J. 2023. Contributions to the herpetofauna of the Angolan Okavango-Cuando-Zambezi River drainages. Part 3: Amphibians. *Amphibian & Reptile Conservation* 17(1 & 2) [General Section]: 19–56 (e325).

**Copyright:** © 2023 Conradie et al. This is an open access article distributed under the terms of the Creative Commons Attribution License [Attribution 4.0 International (CC BY 4.0): <https://creativecommons.org/licenses/by/4.0/>], which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited. The official and authorized publication credit sources, which will be duly enforced, are as follows: official journal title *Amphibian & Reptile Conservation*; official journal website: *amphibian-reptile-conservation.org*.

**Accepted:** 13 April 2023; **Published:** 4 August 2023

## Introduction

In recent years, knowledge on the Angolan herpetofauna has increased dramatically (Marques et al. 2018; Baptista et al. 2019; Branch et al. 2019a). Although reptiles have been the main focus (Conradie et al. 2012a, 2020a, 2021, 2022a,b,c; Stanley et al. 2016; Ceríaco et al. 2020a,b,c;

Marques et al. 2019a,b, 2020, 2022a,b, 2023; Branch et al. 2019a,b, 2021; Hallermann et al. 2020; Lobón-Rovira et al. 2021, 2022; Parrinha et al. 2021; Wagner et al. 2021), several amphibian-focused studies have been published (Conradie et al. 2012b, 2013, 2020b; Ernst et al. 2014, 2015; Conradie and Bills 2016; Ceríaco et al. 2018, 2021; Nielsen et al. 2020; Baptista et al. 2021).

**Correspondence.** \*[werner@bayworld.co.za](mailto:werner@bayworld.co.za); [wernerconradie@gmail.com](mailto:wernerconradie@gmail.com)

From these studies, only six new species of amphibians have been described for Angola since 2012, compared to 35 new species of reptiles (29 lizards and six snakes).

Recent syntheses on the amphibians of Angola documented between 111 and 117 anuran species within the country (Marques et al. 2018; Baptista et al. 2019), although the taxonomic status and presence within Angola remains uncertain for several of these frogs. Approximately 22 species are known only from the type description, singleton records, or incorrect species assignments which no longer apply to the Angolan material (Marques et al. 2018; Baptista et al. 2019). A large proportion of historical type material was lost or destroyed during the Natural History Museum Lisbon fire (Marques et al. 2018), complicating matters further, thus new topotypic material is needed to validate the taxonomical status of various species (Baptista et al. 2019).

Over the last few years, additional amphibian species have been either recorded for the first time from Angola (Conradie et al. 2020b; Ernst et al. 2020) or described as new species (Ceríaco et al. 2018, 2021; Nielsen et al. 2020; Baptista et al. 2021), raising the number of amphibian species known from Angola by at least 13. As more work is done in the country and remote regions are surveyed, a trend similar to reptiles is expected, with the predicted discovery and description of multiple new species.

Southeastern Angola remains amongst the most poorly known regions in Africa (Conradie et al. 2016; Marques et al. 2018; Baptista et al. 2019). Historical amphibian records from this region included only opportunistic collections, most of which were restricted to the western tributaries of the Cubango River basin (Bocage 1895; Monard 1937), and the eastern and northern sections of Moxico Province (Laurent 1964; Monard 1937; Mertens 1938; Ruas 1996, 2002), with only a few records from the Cuito and Cuando river basins (Angel 1924). Recently, based on the outcome of several biodiversity surveys (Brooks 2012, 2013; NGOWP 2017) to document the biodiversity of the Angolan catchment of the Okavango River basin, which comprises the Cubango, Cuito, and Cuando rivers, an updated herpetofauna checklist was compiled (Conradie et al. 2016). A total of 34 species of amphibians were recorded, four of which were new for Angola (*Ptychadena mossambica*, *Sclerophrys poweri*, *Xenopus muelleri*, and *X. poweri*).

The present work serves as the third and final installment of a series of papers documenting the herpetofauna of southeastern Angola, based on surveys performed for the National Geographic Okavango Wilderness Project. The first two installments focused on snakes (Conradie et al. 2021) and on lizards, chelonians, and crocodiles (Conradie et al. 2022c), while this article is restricted to amphibians. The overarching aim of these articles is to document and quantify the herpetofauna of the region, and to contribute to the knowledge of its

conservation importance in both regional and national contexts.

## Materials and Methods

For this study, we present amphibian material and associated data collected during five National Geographic Okavango Wilderness Project (NGOWP) expeditions to south-eastern Angola from 2016 to 2019. See Conradie et al. (2021) for more details on these surveys, a description of the study area, sampling techniques (trapping and visual encounter surveys), and species mapping. Below are some specific methods pertaining to this article.

*Identification and morphology.* Upon completion of the fieldwork component of the study, species were identified based on external morphology, using relevant field guides or published identification keys (Poynton and Broadley 1985a,b, 1987, 1988; Channing 2001; Du Preez and Carruthers 2017; Channing and Rödel 2019) and original type descriptions when needed, and through direct comparisons with material housed in the Port Elizabeth Museum (PEM). Identifications of tadpoles were problematic, as the tadpoles of many of the species collected as adults remain undescribed (see Channing et al. 2012). We tentatively assigned tadpoles based on morphotypes and locality data to the known species until their true identities can be confirmed by genetic analysis. In certain cases, a 16S rRNA barcoding approach was employed to aid in the identification of tadpoles and adults. Laboratory and sequencing protocols followed Conradie et al. (2020b). The Basic Local Alignment Search Tool (BLAST; Altschul et al. 1990) was used to compare our material to the GenBank (<https://www.ncbi.nlm.nih.gov/genbank/>; Benson et al. 2013) repository and our unpublished Angolan dataset. Taxonomy follows Frost (2023) and was updated as needed. Common names follow Channing (2001), Du Preez and Carruthers (2017), and Marques et al. (2018).

The snout-urostyle length (SUL, measured from the tip of the snout to the posterior tip of the urostyle) of adult specimens and the total length of tadpoles were measured to the nearest 0.1 mm, using a digital calliper. All specimens were examined using a Nikon SMZ1270 binocular stereo microscope. For adult frogs, the following information was documented: skin texture, position and number of hand/feet tubercles, webbing condition, and coloration. The webbing formula follows the scheme provided by Rödel (2000). Adult specimens were sexed by confirming the presence/absence of eggs, a gular flap or darkened throats, and nuptial pads. As needed, a small ventral incision was made to look for gonads or testes. No attempt was made to examine stomach contents (which will be the focus of another study). Additionally, the labial tooth rows and oral papillae condition were recorded for tadpoles. Tadpoles are catalogued as ‘lots,’ with specimens from the same locality and collecting event grouped together.





**Fig. 1.** Adult male *Arthroleptis stenodactylus* from Lungwebungu River. Photo by Werner Conradie.

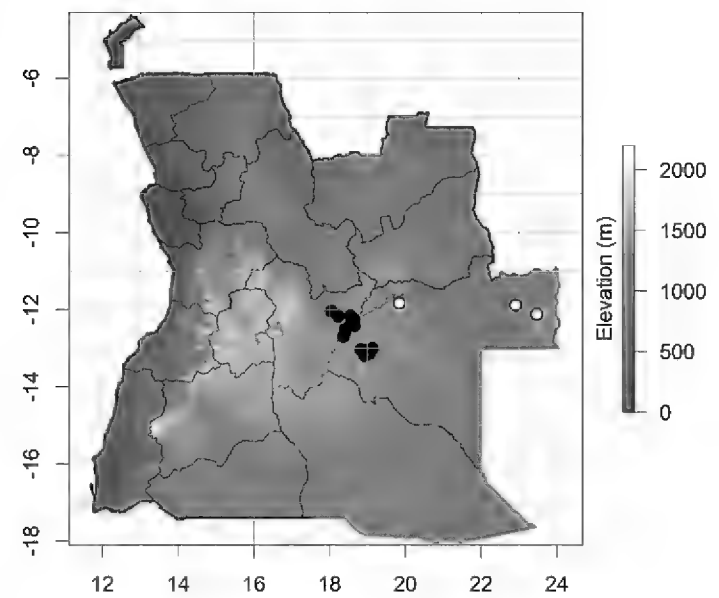
## Results

We documented a total of 1,114 (1,011 adult frogs and 103 tadpole lots) individual amphibian records from ~189 unique localities in southeastern Angola, particularly around the source lakes of the Cuito, Cuanavale, Cuando, and Quembo rivers. A total of 36 species of amphibians (comprising eight families and 20 genera, all from the order Anura) were recorded during this study (Table 1). Information is also reported for one additional species (*Hyperolius quinquevittatus*) that was not collected from within the core study area as previously defined. Updated species occurrence maps are provided for each of the 37 species, reflecting all known localities in Angola (Maps 1–37). For the mapping exercise, a total of 2,507 unique records were collated: 1,062 historical records from Marques et al. (2018), 522 additional literature records, 149 citizen science platform records, 296 records from other sources (GBIF ~ <https://www.gbif.org/>, unpublished records of the PEM, SAIAB, and ZMB collections), and 925 unpublished records from our surveys. This mapping exercise increased the number of new or previously undocumented amphibian records in this study by 58%.

Below we provide a checklist of the amphibians found during these surveys, with each entry including a list of the material examined and comments on identification, habitat, distribution, taxonomy, and natural history notes. Material not collected by the core team or examined for this paper are referred to under ‘Additional material.’ New data used to compile distribution maps can be found in Supplementary Table 1 at: <https://doi.org/10.6084/m9.figshare.23544306.v1>. Abbreviation used: asl – above sea level. Museum and collectors’ codes used: INBAC – Instituto Nacional de Gestão Ambiental; PEM – Port Elizabeth Museum; ZMB – Museum für Naturkunde Berlin (Zoological Collections); SAIAB – South African Institute for Aquatic Biodiversity; P – Pedro vaz Pinto, WC – Werner Conradie.

## Amphibia

### Arthroleptidae



**Map 1.** Distribution of *Arthroleptis stenodactylus* in Angola. Historical records (Marques et al. 2018) are indicated by white dots, while new records are indicated by black dots. Axis values are in degrees (°). Purple polygon – Okavango River basin, Blue polygon – Cuando River basin, Brown polygon – Zambezi River basin.

### *Arthroleptis stenodactylus* Pfeffer, 1893

Common Squeaker (Fig. 1; Map 1)

**Material (43 specimens):** PEM A12495, 4 km upstream from Cuanavale River source lake, -13.05084° 18.89726°, 1,395 m asl; PEM A12501–4, river crossing before Samboano village, -12.30700° 18.62350°, 1,397 m asl; PEM A12526, Munhango village, -12.16310° 18.55430°, 1,421 m asl; PEM A12527, Protea stop en route to Cuito River source, -12.30040° 18.62070°, 1,429 m asl; PEM A12528–36, INBAC: (no number x4), Cuito River source lake, -12.68935° 18.36012°, 1,431 m asl; PEM A12585, 10 km north of Cuemba village, -12.03481° 18.04869°, 1,372 m asl; PEM A13815, en route to Lungwebungu River, -12.25034° 18.63742°, 1,506 m asl; PEM A12616–7, en route road to Cuito River source, -12.55152° 18.41434°, 1,507 m asl; PEM A12618, en route road to Cuito River source, -12.25050° 18.63730°, 1,519 m asl; PEM A12620, drive to Cuanavale River camp from Samanunga village, -13.03803° 18.82977°, 1,623 m asl; PEM A12644, Cuanavale River source lake, -13.18067° 18.92172°, 1,340 m asl; PEM A12647, stop on road to Cuito River source, -12.50584° 18.41382°, 1,556 m asl; PEM A12648–9, camp 1 en route to Cuito River source, -12.35920° 18.56280°, 1,510 m asl; PEM A12729, Cuando River source, -13.00346° 19.12751°, 1,346 m asl; PEM A12803–4, Lake Tchanssengwe, -12.41402° 18.64418°, 1,415 m asl; PEM A12843–50, INBAC: (no number x2), Quembo River source lake, -13.13624° 19.04591°, 1,411 m asl. **Additional records:** P2-276 (photograph and tissue sample), wetland near old quarry east of Quemba, -12.16960° 18.22965°, 1,353 m asl. **Description:** Medium sized *Arthroleptis*; stocky build; rounded snout; tympanum clearly visible; well-developed inner metatarsal tubercle; no webbing; toe tips not dilated. Dorsum uniformly beige to pink, with scattered white speckles; no darker hourglass pattern observed on dorsum; yellow vertebral stripe either

## Amphibians of the Okavango Delta headwater area in Angola

**Table 1.** Records of amphibians for the Angolan Okavango-Cuando-Zambezi river basins. ? = not recorded from the core study area, but expected to occur based on peripheral records.

Species	Okavango River Basin	Cuando River Basin	Zambezi River Basin	Source of records
<b>ARTHROLEPTIDAE</b>				
<i>Arthroleptis stenodactylus</i> Pfeffer, 1893	X	X	X	This study; Ruas 1996
<i>Arthroleptis xenochirus</i> Boulenger, 1905	X	X	X	This study; Ruas 1996
<i>Leptopelis anchietae</i> (Bocage, 1873)	X			This study; Monard 1937; Conradie et al. 2016
<i>Leptopelis bocagii</i> (Günther, 1865)	X	X	X	This study
<i>Leptopelis</i> sp.	X	X	X	This study
<b>BREVICIPITIDAE</b>				
<i>Breviceps ombelanonga</i> Nielsen, Conradie, Ceríaco, Bauer, Heinicke, Stanley, and Blackburn, 2020	X	X	X	This study; Bocage 1895; Monard 1937; Ruas 1996
<b>BUFONIDAE</b>				
<i>Mertensophryne melanopleura</i> (Schmidt and Inger, 1959)			X	Ruas 1996
<i>Poyntonophrynus kavangensis</i> (Poynton and Broadley, 1988)			X	Ruas 1996
<i>Schismaderma carens</i> (Smith, 1848)			X	Laurent 1964
<i>Sclerophrys funerea</i> (Bocage, 1866)	X		X	Monard 1937; Laurent 1964; Ruas 1996; Conradie et al. 2016
<i>Sclerophrys gutturalis</i> (Power, 1927)	X	X	X	This study; Monard 1937; Ruas 1996; Conradie et al. 2016
<i>Sclerophrys pusilla</i> (Mertens, 1937)	X	X	X	This study
<i>Sclerophrys poweri</i> (Hewitt, 1935)	X		X	This study; Conradie et al. 2016
<i>Sclerophrys lemairii</i> (Boulenger, 1900)	X		X	Ruas 1996; Conradie et al. 2016
<b>HEMISOTIDAE</b>				
<i>Hemisus guineensis</i> Cope, 1865	X	X	X	This study; Monard 1937; Laurent 1964
<b>HYPEROLIIDAE</b>				
<i>Hyperolius benguellensis</i> (Bocage, 1893)	X	X	X	This study; Conradie et al. 2016
<i>Hyperolius cinereus</i> Monard, 1937	X			This study; Conradie et al. 2016
<i>Hyperolius</i> cf. <i>inyangae</i> Channing, 2013		X	X	This study
<i>Hyperolius nasutus</i> Günther, 1865	X	X	X	This study; Monard 1937; Conradie et al. 2016
<i>Hyperolius parallelus</i> Günther, 1858	X	X	X	This study; Conradie et al. 2016
<i>Hyperolius raymondi</i> Conradie, Branch, and Tolley, 2013	X	X	X	This study
<i>Hyperolius quinquevittatus</i> Bocage, 1866	?		?	This study
<i>Hyperolius</i> aff. <i>bocagei</i> Steindachner, 1867	X	X	X	This study



**Table 1 (continued).** Records of amphibians for the Angolan Okavango-Cuando-Zambezi river basins. ? = not recorded from the core study area, but expected to occur based on peripheral records.

Species	Okavango River Basin	Cuando River Basin	Zambezi River Basin	Source of records
<i>Kassina kuvangensis</i> (Monard, 1937)	X	X	X	This study; Monard 1933, 1937; Conradie et al. 2016
<i>Kassina senegalensis</i> (Duméril and Bibron, 1841)	X	X	X	This study; Monard 1933, 1937; Conradie et al. 2016
<i>Kassinula wittei</i> Laurent, 1940	X	X	X	This study; Conradie et al. 2021
<b>MICROHYLIDAE</b>				
<i>Phrynomantis affinis</i> Boulenger, 1901			X	Ruas 1996
<b>PHRYNOBATRACHIDAE</b>				
<i>Phrynobatrachus mababiensis</i> FitzSimons, 1932 complex	X	X	X	This study; Conradie et al. 2016 This study; Monard 1937; Ruas 1996; Conradie et al. 2016
<i>Phrynobatrachus natalensis</i> (Smith, 1849)	X	X	X	1996; Conradie et al. 2016
<i>Phrynobatrachus parvulus</i> (Boulenger, 1905)	X	X		Conradie et al. 2016
<b>PIPIDAE</b>				
<i>Xenopus muelleri</i> (Peters, 1844)	X	X		Conradie et al. 2016 This study; Monard 1937; Ruas 1996; Conradie et al. 2016
<i>Xenopus petersii</i> Bocage, 1895	X	X	X	1996; Conradie et al. 2016
<i>Xenopus poweri</i> Hewitt, 1927		X	X	This study; Conradie et al. 2016
<b>PTYCHADENIDAE</b>				
<i>Hildebrandtia ornatissima</i> (Bocage, 1879)	X			Bocage 1895; Monard 1937a; Ruas 1996
<i>Ptychadena anchietae</i> (Bocage, 1868)			X	Ruas 1996
<i>Ptychadena bunoderma</i> (Boulenger, 1907)	X	X		This study
<i>Ptychadena grandisonae</i> Laurent, 1954	X		X	This study; Ruas 1996
<i>Ptychadena guibei</i> (Laurent, 1954)			X	Ruas 1996
<i>Ptychadena keilingi</i> (Monard, 1937)	X	X	X	This study; Ruas 1996
<i>Ptychadena nilotica</i> (Seetzen, 1855)	X		X	Ruas 1996; Conradie et al. 2016
<i>Ptychadena mossambica</i> (Peters, 1854)		X		Conradie et al. 2016 This study; Monard 1937a; Conradie et al. 2016
<i>Ptychadena oxyrhynchus</i> (Smith, 1849)	X	X		
<i>Ptychadena porosissima</i> (Steindachner, 1867)	X		X	This study This study; Ruas 1996; Conradie et al. 2016
<i>Ptychadena subpunctata</i> (Bocage, 1866)	X	X	X	This study; Ruas 1996; Conradie et al. 2016
<i>Ptychadena taenioscelis</i> Laurent, 1954	X	X	X	This study; Ruas 1996; Conradie et al. 2016
<i>Ptychadena upembae</i> (Schmidt and Inger, 1959)	X		X	This study; Ruas 1996; Conradie et al. 2016 (as <i>P. guebei</i> )

**Table 1 (continued).** Records of amphibians for the Angolan Okavango-Cuando-Zambezi river basins. ? = not recorded from the core study area, but expected to occur based on peripheral records.

Species	Okavango River Basin	Cuando River Basin	Zambezi River Basin	Source of records
<i>Ptychadena uzungwensis</i> (Loveridge, 1932)	X	X	X	This study; Ruas 1996; Conradie et al. 2016
<b>PYXICEPHALIDAE</b>				
<i>Amietia angolensis</i> (Bocage, 1866)	X		X	This study; Ruas 1996; Conradie et al. 2016
<i>Tomopterna tuberculosa</i> (Boulenger, 1882)	X		X	This study; Bocage 1895; Monard 1937; Ruas 1996
<b>RANIDAE</b>				
<i>Amnirana adiscifera</i> (Schmidt and Inger, 1959) <b>stat. nov.</b>	X	X	X	This study; Ruas 1996; Conradie et al. 2016
<i>Amnirana lemairei</i> (De Witte, 1921)			X	Ruas 1996
<b>Species total: 51</b>	<b>40</b>	<b>31</b>	<b>42</b>	

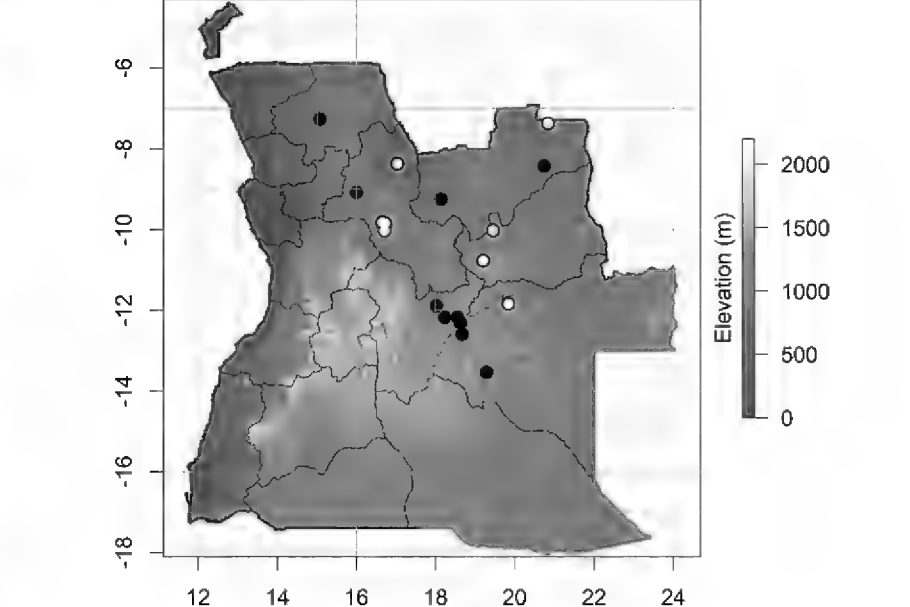
absent (n = 23) or present (n = 12); faint dark facial mask from tip of snout to the eye, continuous to the arm; ventrum immaculate. Breeding males with dark throats; minute spines on lower back; elongated 3<sup>rd</sup> finger, with spines on the inner side and to the tip. Adult females (n = 11) varied from 32.6–37.7 (34.6 average) mm SUL (largest female: PEM A12846); adult males (n = 4) varied from 19.5–23.6 (21.5) mm (largest male: PEM A12804). **Habitat and natural history notes:** All specimens were collected in miombo woodland. Gravid females were collected in October/November. Males were heard calling on overcast days and evenings after rain. In February/March, juveniles and subadults were abundant, but no adults were collected or heard calling. **Comments:** Historically, this species was only known from three records from eastern Angola (Marques et al. 2018). Our new material shows that this species is more

common in eastern Angola than previously recognized. This was expected as it is widespread to the east of the Zambian border (Poynton and Broadley 1985a, 1991; Channing 2001). Additionally, these are the first confirmed records from the Okavango River basin. Studies have shown that *A. stenodactylus* comprises two distinct ecomorphs that occur in different habitats. One form, to which our material belongs, prefers drier savanna, while the other form is known from montane forests (Loveridge 1953; Pickersgill 2007; Bittencourt-Silva et al. 2020).

*Arthroleptis xenochirus* Boulenger, 1905  
Plain Squeaker (Fig. 2; Map 2)  
**Material (8 specimens):** PEM A12505–7, river crossing before Samboano Village, -12.30700° 18.62350°, 1,398 m asl; PEM A12910–1, Muhango village, -12.16067° 18.55042°, 1,430 m asl; PEM A14696–7, Lungwebungu



**Fig. 2.** Adult male *Arthroleptis xenochirus* from Muhango town. Photo by Werner Conradie.



**Map 2.** Distribution of *Arthroleptis xenochirus* in Angola.

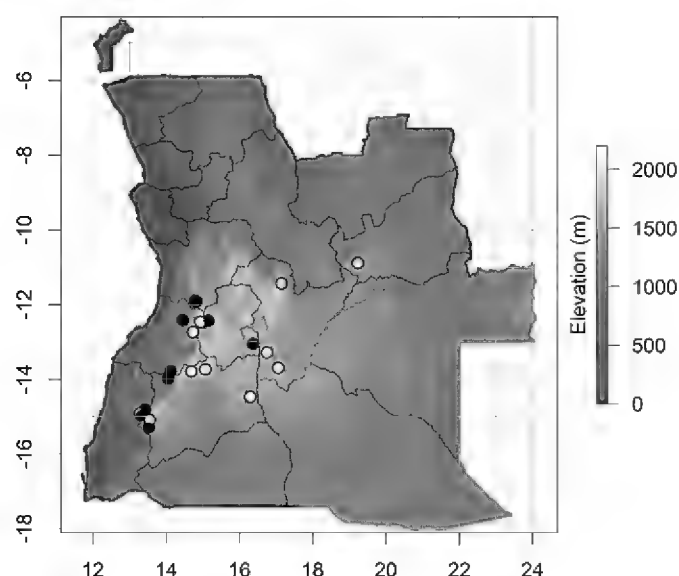


River camp, -12.58439° 18.66748°, 1,297 m asl; PEM A14777, Quembo River bridge camp, -13.52746° 19.2806°, 1,241 m asl. **Additional material:** P2-272 (photograph and tissue sample), wetland near old quarry east of Quemba, -12.16960° 18.22965°, 1,353 m asl.

**Description:** A small species of *Arthroleptis*; slender body; pointed snout; small tympanum, not always clearly visible; well-developed inner metatarsal tubercle; no webbing; slightly dilated toe tips. Dorsal color varies from beige to brown, with some red infusion; dark facial mask from snout to eye, continuing to just above arm; white markings on grey colored jawline; all specimens have a darkened hour-glass pattern on the back; ventrum immaculate. Breeding males with dark throats; elongated 3<sup>rd</sup> finger, with no spines. Single adult female measured 20.9 mm (PEM A14777); adult males (n = 4) varied from 19.5–23.6 (21.5) mm (largest male: PEM A14697). **Habitat and natural history notes:** All specimens were collected in miombo woodland. Males were heard calling in October/November. Gravid female collected in November, while only juveniles and subadults were collected in February/March. **Comments:** Known from central and northern Angola (Marques et al. 2018). The record from lower Quembo River represents the southernmost record for the species, and the first record associated with the Okavango River basin.

*Leptopelis anchietae* (Bocage, 1873)  
Anchieta's Tree Frog (Map 3)

**Material (1 tadpole lot):** PEM A14174 (five tadpoles), Cubango River campsite below rapids, west of Fundo village, -13.04260° 16.37476°, 1,559 m asl. **Description:** Elongated tadpoles; 20.8–30.6 mm total length, with tail 2.6–3.1 times the body length. Body is dark brown to black, ventrum with scattered light golden spots; lateral tail muscle dark brown to black, with two lighter bands from body to tail tip; posterior half of tail black. The labial tooth row formula (LTRF) is 3(2–3)/3(1); jaw sheaths are heavily keratinized; anterior part of mouth free of elongated marginal papillae. **Habitat and natural history notes:** Tadpoles were collected in a flooded grassland next to the main river. **Comments:**



**Map 3.** Distribution of *Leptopelis anchietae* in Angola.

Identification of tadpoles was confirmed by 16S rRNA barcoding (N. Baptista, unpub. data) and compared to the description in Channing et al. (2012). This Angolan endemic species occurs mostly in the highlands of central and western Angola (Becker et al., in prep.), and many of the old historical records (e.g., Marques et al. 2018) are based on incorrect identifications or erroneous locality data (Pedro vaz Pinto, pers. comm.).

*Leptopelis bocagii* (Günther, 1865)

Bocage's Tree Frog (Figs. 3–4; Map 4)

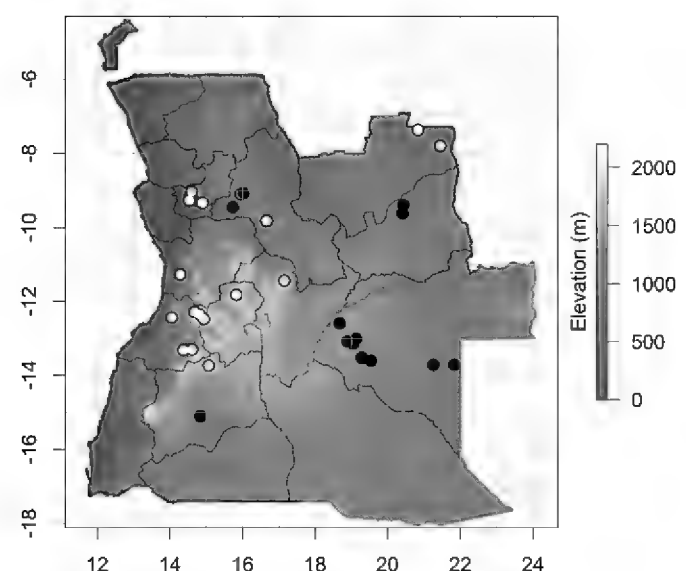
**Material (46 specimens):** PEM A12701–10, Lungwebungu River camp bridge crossing, -12.58347° 18.66598°, 1,304 m asl; PEM A12742–6, Cuando



**Fig. 3.** Adult male *Leptopelis bocagii* (brown form) from Cuando River source. Photo by James Harvey.



**Fig. 4.** Adult male *Leptopelis bocagii* (green form) from Cuanavale River side tributary source. Photo by Luke Verburgt.



**Map 4.** Distribution of *Leptopelis bocagii* in Angola.

River source, -13.00346° 19.12751°, 1,346 m asl; PEM A12772–4, INBAC: WC-4634, Cuanavale River side tributary source, -13.07452° 18.88345°, 1,385 m asl; PEM A12873–80, INBAC: WC-4669 and 4672, Quembo River source lake, -13.13624° 19.04591°, 1,411 m asl; PEM A14688–9, Lungwebungu River camp, massambas on left side of river, -12.58276° 18.66556°, 1,295 m asl; PEM A14701–4, INBAC: WC-6763, Lungwebungu River camp, -12.58439° 18.66748°, 1,297 m asl; PEM A14723, PEM A14742, Quembo River bridge camp, -13.52746° 19.28060°, 1,241 m asl; PEM A14741, Quembo River bridge camp, trap 3, -13.52778° 19.27455°, 1,256 m asl; PEM A14755–6, PEM A14758–9, INBAC: WC-6994, Quembo River right side tributary (Micongo River) past village, -13.51877° 19.28487°, 1,248 m asl; PEM A14823, camp at side tributary (Luandai River) of the Luanguinga River, -13.70885° 21.26234°, 1,116 m asl; PEM A14891, Luvu River camp, -13.71200° 21.83538°, 1,082 m asl. **Description:** Large terrestrial tree frog; broad rounded head; large protruding eyes; tympanum clearly visible; large well-developed inner metatarsal tubercle; no webbing or expanded toe tips. Dorsum varied from green to brown, with dark horseshoe pattern on the back, and dark interorbital bar; dark facial mask from snout to eye, continuing to above arm; sides of body with scattered black spots or continuous black bar between limbs; scattered white speckles on dorsum; ventrum immaculate. Breeding males with dark throat and weakly developed pectoral glands. Adult females (n = 12) varied from 41.5–67.8 (57.9) mm (largest female: PEM A12746); adult males (n = 34) varied from 43.0–56.8 (48.6) mm (largest male: INBAC: WC-4669). **Habitat and natural history notes:** Collected along the sandy margins of source lakes or rivers associated with miombo woodland. Frequently encountered in the clearings of agricultural fields near water sources. Males were found calling from the ground. **Comment.** These are the first records from eastern Angola, bridging the distribution gap between western Angola and Zambia (Broadley 1971; Marques et al. 2018; Baptista et al. 2019).

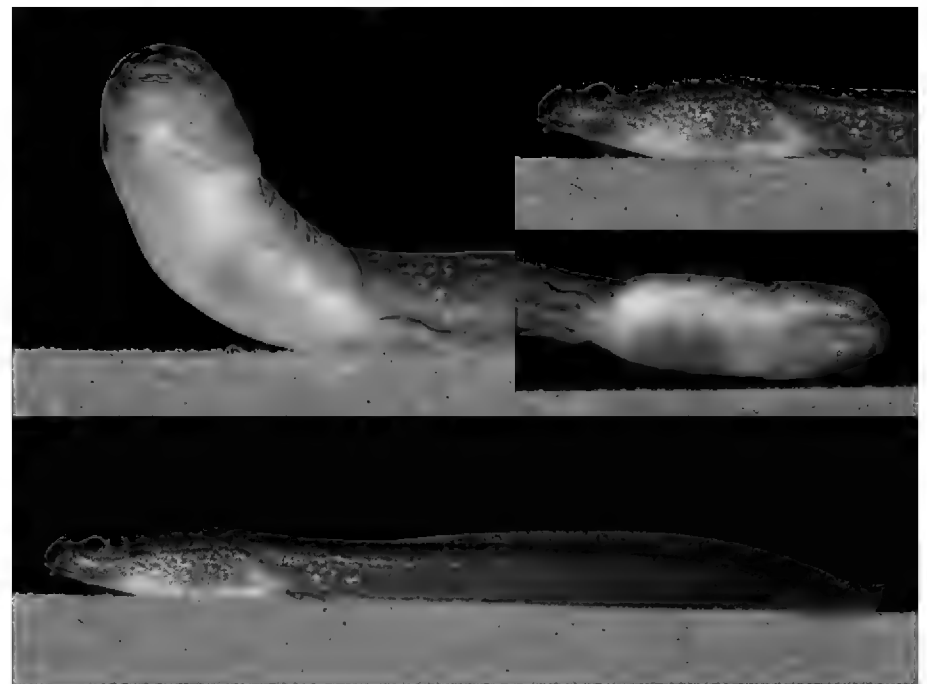
#### *Leptopelis* sp.

Unidentified Tree Frog (Figs. 5–6; Map 5)

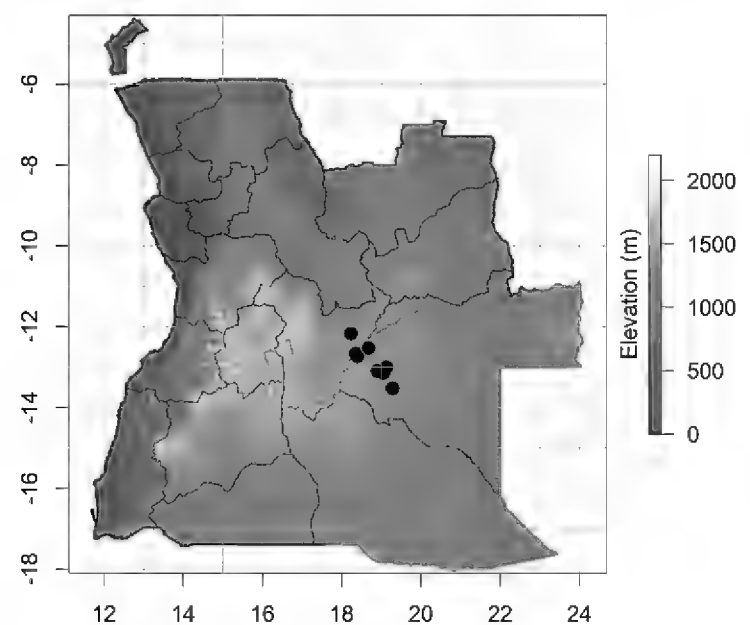
**Material (34 specimens, 2 tadpole lots):** PEM A12801–2, Cuanavale River source lake, -13.08934° 18.89485°, 1,359 m asl; PEM A12882–8, Quembo River source lake, -13.13624° 19.04591°, 1,396 m asl; PEM A12794–5, INBAC: WC-4685 and no number, Cuanavale River source lake, -13.09442° 18.89372°, 1,368 m asl; PEM A12747–51, INBAC: WC-4754 and no number, Cuando River source, -13.00346° 19.12751°, 1,353 m asl; PEM A14118 (tadpoles), Calua River source, 6 km SE of Cuito River source, -12.73675° 18.39310°, 1,446 m asl; PEM A13845–6, PEM A14123 (tadpoles), Cuiva River source, -12.66825° 18.35282°, 1,407 m asl; PEM A12786, Cuando River source, trap



**Fig. 5.** Adult male *Leptopelis* sp. from Cuanavale River source. Photo by Luke Verburgt.



**Fig. 6.** Tadpole of *Leptopelis* sp. from Cuiva River source. Photo by Werner Conradie.



**Map 5.** Distribution of *Leptopelis* sp. in Angola.

4, -13.00164° 19.12960°, 1,361 m asl; PEM A12819–21, Cuiva River source, -12.66856° 18.35307°, 1,433 m asl; PEM A14775, INBAC: WC-6852, Quembo River bridge camp, -13.52746° 19.28060°, 1,241 m asl; PEM A14767–74, Quembo River right side tributary (Micongo River) past village, -13.51877° 19.28487°, 1,248 m asl. **Additional material (3 specimens):** P2-277, wetland near old quarry east of Quemba, -12.16960° 18.22965°, 1,353 m asl; SAIAB 209098 (2 specimens),

Quembo River source lake,  $-13.14025^{\circ}$   $19.04822^{\circ}$ , 1,365 m asl. **Description:** Small terrestrial tree frog; large protruding eyes; tympanum clearly visible; well-developed rounded inner metatarsal tubercle; reduced webbing; digit tips slightly dilated (slightly wider than finger), finger tips more dilated than toe tips. Dorsum tan-brown; dark brown interorbital bar often present; dark brown vertebral stripe from just behind head to vent; some individuals with extra paravertebral bands; dark brown facial mask extending past arm onto side of body; scattered white speckles; groin with scattered unpigmented skin, extending onto the limbs; throat darkly pigmented; ventrum immaculate. Males with weakly developed pectoral glands and darkened throats. Adult females ( $n = 2$ ) varied from 36.6–40.7 (38.7) mm (largest female: PEM A12786); adult males ( $n = 35$ ) varied from 29.0–34.6 (31.1) mm (largest male: PEM A12883). Elongated brown tadpoles; 40.7–52.2 mm total length, with tail 3.2 times body length; strong tail muscle starting just behind eye; thin fin margin above and below; LTRF 2(1)/3(1); jaw sheaths heavily keratinized, anterior part free of elongated marginal papillae. **Habitat and natural history notes:** Males were found calling in trees and shrubs (0.5–3 m above the ground), which were often located far from water, in grasslands with sparse tree cover. As the rainy season progressed, calls were heard progressively closer to water bodies, until eventually being heard among vegetation in the wetlands. The call resembles a chuckle. The eel-like tadpoles were found in wetlands among dense aquatic vegetation. **Comments:** Unusual light pink/red eel-like tadpoles were initially found in wetlands at the source of two different river systems, the Cuito and Kwanza rivers, in February 2016. A small number of these tadpoles were raised to adults in captivity. Nearly seven months were required to reach metamorphosis, during which time they changed from light pink/red to a more brownish coloration. They seemed to be sensitive to light as they swam erratically when removed from a dark environment and exposed to bright light. During the start of the rainy season in October 2016, unusual calls were heard which could not

be assigned to a known species. After triangulation, several individuals were found calling from trees or shrubs, which were often far from water. On closer inspection, these specimens were found to be morphologically identical to the ones raised in captivity. We subsequently found these frogs at all major river sources and along rivers. Barcode analysis (16S rRNA) recovered the unknown *Leptopelis* as similar to *L. ocellatus* (94% similarity; KY080253), but the latter is a forest species with well-developed discs on toes. Schmidt and Inger (1959) described *Leptopelis parvus* from the Democratic Republic of the Congo (DRC), which resembles our *Leptopelis* sp. because of its small size and the shared absence of a white stripe above the vent that stretches onto the legs. However, our specimens differ from *L. parvus* in dorsal coloration pattern (para- and vertebral stripe present versus absent in *L. parvus*), lack of discs (dilated toe tips, but no clear discs versus clear discs in *L. parvus*), and pectoral glands (present versus absent in *L. parvus*). Further phylogenetic and morphological work is needed to resolve the taxonomic status of this species.

### Brevicipitidae

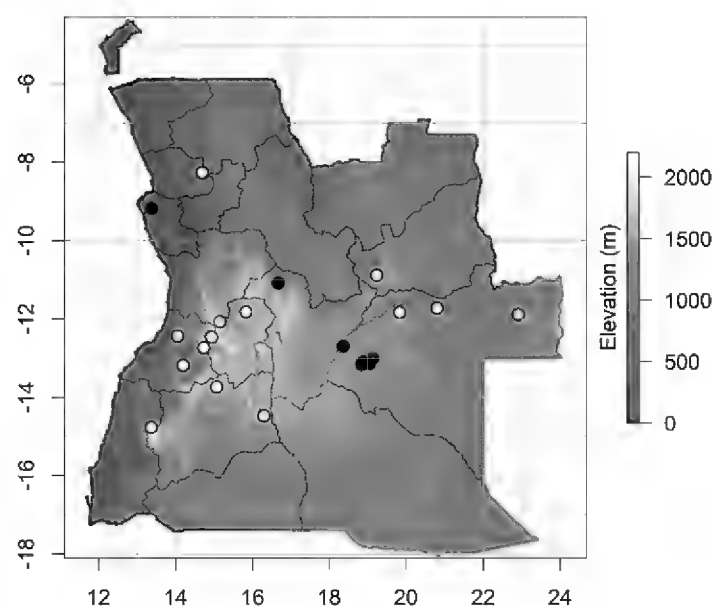
*Breviceps ombelanonga* Nielsen, Conradie, Ceriaco, Bauer, Heinicke, Stanley, and Blackburn, 2020

Angolan Rain Frog (Fig. 7; Map 6)

**Material (4 specimens):** PEM A12787, Quembo River source lake,  $-13.13544^{\circ}$   $19.04397^{\circ}$ , 1,374 m asl; PEM A12800, Cuanavale River source lake,  $-13.08934^{\circ}$   $18.89485^{\circ}$ , 1,359 m asl; PEM A12770, Cuando River source,  $-13.00334^{\circ}$   $19.13564^{\circ}$ , 1,362 m asl; PEM A12537, Cuito River source lake,  $-12.68935^{\circ}$   $18.36012^{\circ}$ , 1,431 m asl. **Additional material (1 specimen):** SAIAB 204537, Quembo River source lake,  $-13.13583^{\circ}$   $19.04528^{\circ}$ , 1,370 m asl. **Description:** Medium sized *Breviceps*; stout body; snout extremely shortened; pupils horizontally elliptical; tympanum not visible; outer metacarpal tubercle flat and undivided; short limbs; webbing absent; well-developed inner metatarsal tubercle fused with the outer metatarsal tubercle, with no deep cleft present, elongated, and



**Fig. 7.** Adult male *Breviceps ombelanonga* from Cuanavale River source. Photo by Luke Verburgt.



**Map 6.** Distribution of *Breviceps ombelanonga* in Angola.



protruding outwards. Coloration varied from red with scattered black blotches, dark brown with red spots and markings, and light brown with red spots and black blotches (Nielsen et al. 2020). The only female collected measured 30.1 mm (PEM A12770); adult males ( $n = 3$ ) varied from 18.3–26.6 (26.2) mm (largest male: PEM A12787). **Habitat and natural history notes:** Males were only heard calling during the day, especially after heavy rains; calling did not continue into the evenings. Call sites were among leaf litter in dense miombo woodland. **Comments:** The taxonomic status of Angolan *Breviceps* was recently addressed, leading to the description of this material as a new species, *B. ombelanonga* (Nielsen et al. 2020). Broader sampling across Angola may detect the presence of other species (e.g., *B. adspersus* to the south and *B. poweri* to the east) and even additional undescribed species. For now, all historical records are mapped as *B. ombelanonga*, until their taxonomic status can be confirmed.

### Bufonidae

#### *Sclerophrys gutturalis* (Power, 1827)

Guttural Toad (Fig. 8; Map 7)

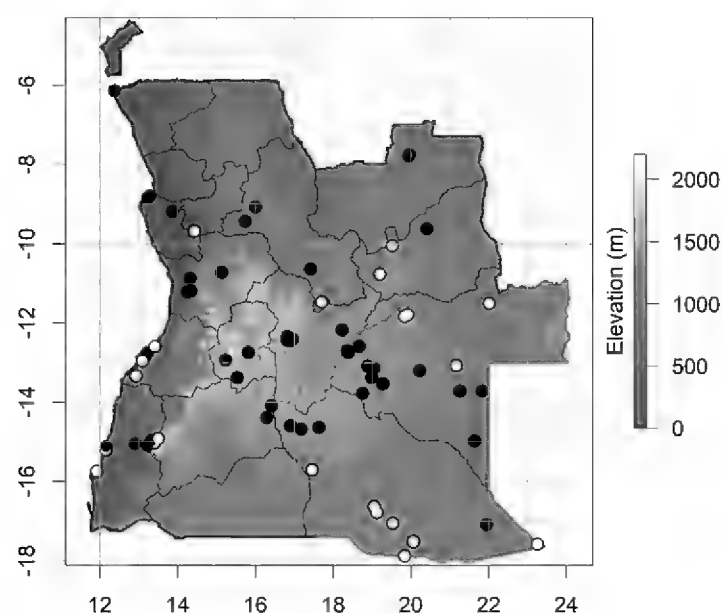
**Material (69 specimens):** PEM A12484, INBAC: WC-4841–2, Cuanavale River source lake,  $-13.08537^{\circ}$   $18.89098^{\circ}$ , 1,360 m asl; PEM A12498, drive back from Cuchi to Menongue,  $-14.67986^{\circ}$   $17.17512^{\circ}$ , 1,404 m asl; PEM A12573–5, Cuito River source lake,  $-12.68935^{\circ}$   $18.36012^{\circ}$ , 1,431 m asl; PEM A12612, Calua River source, 6 km SE of Cuito River source,  $-12.73675^{\circ}$   $18.39310^{\circ}$ , 1,442 m asl; PEM A12625–6, HALO Cuito,  $-12.39584^{\circ}$   $16.96067^{\circ}$ , 1,697 m asl; PEM A12629, roadside ditch 10 km SW of Cuito town,  $-12.44815^{\circ}$   $16.88118^{\circ}$ , 1,742 m asl; PEM A12639, PEM A12643, Cuanavale River,  $-13.37406^{\circ}$   $18.99269^{\circ}$ , 1,304 m asl; PEM A12677–9, INBAC: WC-5232, Camp 3, Malova Village, Mipanha River,  $-14.09140^{\circ}$   $16.41476^{\circ}$ , 1,553 m asl; PEM A12685, Huambo HALO training camp,  $-12.73726^{\circ}$   $15.81828^{\circ}$ , 1,665 m asl; PEM A12698, Cuando River bridge,  $-13.60757^{\circ}$   $19.53257^{\circ}$ , 1,277 m asl; PEM A12719–25,

Lungwebungu River camp bridge crossing,  $-12.58346^{\circ}$   $18.66598^{\circ}$ , 1,304 m asl; PEM A12796–7, Cuanavale River source lake camp side,  $-13.09442^{\circ}$   $18.89372^{\circ}$ , 1,368 m asl; PEM A12907–8, INBAC: no number (x2), Quembo River source lake,  $-13.13624^{\circ}$   $19.04591^{\circ}$ , 1,366 m asl; PEM A13763, Lungwebungu River, trap 2,  $-12.58199^{\circ}$   $18.66562^{\circ}$ , 1,208 m asl; PEM A13781, Lungwebungu River, trap 3,  $-12.58056^{\circ}$   $18.66419^{\circ}$ , 1,302 m asl; PEM A13784, Cuquema River, downstream,  $-12.47021^{\circ}$   $16.82334^{\circ}$ , 1,644 m asl; PEM A13790, Dam/Hydroplant on Cuquema River,  $-12.42556^{\circ}$   $16.81856^{\circ}$ , 1,640 m asl; PEM A14680, Menongue,  $-14.63015^{\circ}$   $17.63465^{\circ}$ , 1,373 m asl; PEM A14685, wetland near old quarry east of Quemba,  $-12.16960^{\circ}$   $18.22965^{\circ}$ , 1,353 m asl; PEM A14712–5, INBAC: WC-6975, Lungwebungu River camp,  $-12.58439^{\circ}$   $18.66748^{\circ}$ , 1,297 m asl; PEM A14724, Quembo River bridge,  $-13.52746^{\circ}$   $19.28060^{\circ}$ , 1,241 m asl; PEM A14739, Quembo River bridge camp, trap 1,  $-13.52801^{\circ}$   $19.28147^{\circ}$ , 1,236 m asl; PEM A14740, Quembo River bridge camp,  $-13.52746^{\circ}$   $19.28060^{\circ}$ , 1,241 m asl; PEM A14744, Quembo River bridge camp, trap 4,  $-13.52658^{\circ}$   $19.27810^{\circ}$ , 1,248 m asl; PEM A14818–22, INBAC: WC-7004, Luio River camp floodplains,  $-13.19711^{\circ}$   $20.22194^{\circ}$ , 1,181 m asl; PEM A14824–6, INBAC: WC-7029, Camp at side tributary (Luandai River) of the Luanguinga River,  $-13.70885^{\circ}$   $21.26234^{\circ}$ , 1,116 m asl; PEM A14831, Luanguinga River waterfall,  $-13.71132^{\circ}$   $21.24914^{\circ}$ , 1,118 m asl; PEM A14851–5, INBAC: WC-7044, Lake Hundo,  $-14.97431^{\circ}$   $21.62966^{\circ}$ , 1,100 m asl; PEM A14889–90, INBAC: WC-7079, Luvu River camp,  $-13.71200^{\circ}$   $21.83538^{\circ}$ , 1,082 m asl.

**Description:** Large robust toad; snout rounded; elevated parotoid glands. Dorsum dark brown with pairs of dark paravertebral patches; pairs of dark patches on snout and behind eyes that create the appearance of a pale cross on head; in PEM A12724 and A12720 a continuous dark interorbital bar is present; back of thighs often with red infusions (not always present in females or juveniles). In breeding males, the dorsum becomes yellow, with numerous small black-tipped asperites; throat darkened; enlarged arms; black nuptial pads present on palm and



**Fig. 8.** Adult male *Sclerophrys gutturalis* from Lungwebungu River source. Photo by Werner Conradie.



**Map 7.** Distribution of *Sclerophrys gutturalis* in Angola.

first finger. Adult females ( $n = 22$ ) varied from 54.4–109.7 (78.3) mm (largest female: PEM A12575); adult males ( $n = 37$ ) varied from 56.7–89.2 (74.6) mm (largest male: PEM A14890). **Habitat and natural history notes:** Found in miombo woodland. Males were heard calling from margins of the source lakes. **Comments:** Widespread species across most of south-central Africa (Channing and Rödel 2019). Most historical Angolan material has been referred to as *Bufo regularis* Reus, 1833. Since the description of *Bufo regularis gutturalis* Power, 1927 (subsequently elevated to full species), the Angolan material has only partly been reassigned (Ruas 1996), and the rest of the extant material needs to be reassessed to verify the taxonomic status. Additionally, this species needs to be reassessed as other authors have demonstrated that cryptic species may be present in this taxon (Pickersgill 2007; Telford et al. 2019).

*Sclerophrys pusilla* (Mertens, 1937)

Flat-backed Toad (Fig. 9; Map 8)

**Material (41 specimens):** PEM A12425–6, INBAC (no number), Cunde waterfall,  $-13.77364^{\circ}$   $18.75514^{\circ}$ , 1,287 m asl; PEM A12434, south of Menongue en route to Cueba River,  $-14.96288^{\circ}$   $17.69090^{\circ}$ , 1,319 m asl; PEM A12446, Cuchi River gorge,  $-14.59000^{\circ}$   $16.90758^{\circ}$ , 1,375 m asl; PEM A12494, HALO Menongue,  $-14.66317^{\circ}$   $17.66521^{\circ}$ , 1,386 m asl; PEM A12499, INBAC (no number), drive back from Cuchi to Menongue,  $-14.67986^{\circ}$   $17.17512^{\circ}$ , 1,404 m asl; PEM A12623–4, HALO Cuito,  $-12.39584^{\circ}$   $16.96067^{\circ}$ , 1,697 m asl; PEM A12630–1, roadside ditch 10 km SW of Cuito,  $-12.44815^{\circ}$   $16.88118^{\circ}$ , 1,742 m asl; PEM A12636, Quembo River source camp,  $-13.52653^{\circ}$   $19.28368^{\circ}$ , 1,242 m asl; PEM A12640, Cuanavale River,  $-13.37406^{\circ}$   $18.99269^{\circ}$ , 1,297 m asl; PEM A12642, Cuanavale River,  $-13.29236^{\circ}$   $18.96283^{\circ}$ , 1,313 m asl; PEM A 12650–1, Kwanza River bridge,  $-11.99348^{\circ}$   $17.66965^{\circ}$ , 1,273 m asl; PEM A12652, Kuvango Hydro Plant Site, wetland to east,  $-14.38755^{\circ}$   $16.30166^{\circ}$ , 1,451 m asl; PEM A12658, old Kuvango Hydroplant site,  $-14.38775^{\circ}$   $16.29365^{\circ}$ , 1,440 m asl; PEM A12659–60, Campsite 2 near Cuvango Mission,  $-13.32887^{\circ}$   $16.41167^{\circ}$ , 1,537 m asl; PEM A12668, Campsite 1 below rapids,

west of Fundo village,  $-13.04483^{\circ}$   $16.37520^{\circ}$ , 1,565 m asl; PEM A12680, Camp 3, Malova Village, Mipanha River,  $-14.09140^{\circ}$   $16.41476^{\circ}$ , 1,553 m asl; PEM A12686–7, Huambo HALO training camp,  $-12.73726^{\circ}$   $15.81828^{\circ}$ , 1,665 m asl; PEM A12690, Cubango 2017 launch site,  $-12.61700^{\circ}$   $16.22132^{\circ}$ , 1,727 m asl; PEM A12839, 31 km W of Menongue, Cueli River,  $-14.70511^{\circ}$   $17.38014^{\circ}$ , 1,392 m asl; PEM A13791, Dam/Hydroplant on Cuquema River,  $-12.42556^{\circ}$   $16.81856^{\circ}$ , 1,640 m asl; PEM A14681–2, Menongue,  $-14.63015^{\circ}$   $17.63465^{\circ}$ , 1,373 m asl; PEM A14720–1, 14725, Quembo River bridge,  $-13.52746^{\circ}$   $19.28060^{\circ}$ , 1,241 m asl; PEM A14745–7, Quembo River bridge camp,  $-13.52746^{\circ}$   $19.28060^{\circ}$ , 1,241 m asl; PEM A17761–2, Quembo River right side tributary (Micongo River) past village,  $-13.51877^{\circ}$   $19.28487^{\circ}$ , 1,478 m asl. **Description:** Medium sized toad; sharp snout profile; small flattened parotoid glands. Light brown dorsal coloration, with irregular darker markings; no interorbital bar; thin light dorsal stripe may be present; no red markings on the back of the thighs. Males with darkened throats; dorsum with black tipped asperites. Adult females ( $n = 16$ ) varied from 52.1–79.3 (65.9) mm (largest female: PEM A14745); adult males ( $n = 9$ ) varied from 35.5–58.7 (50.3) mm (largest male: PEM A12839). **Habitat and natural history notes:** Found in miombo woodland, sympatric with *S. gutturalis*. **Comments:** Poynton et al. (2016) recently split West Africa *S. maculata* from central and southern African *S. pusilla*. All the historical Angolan material referred to under the former name, *S. maculata*, now represents *S. pusilla*.

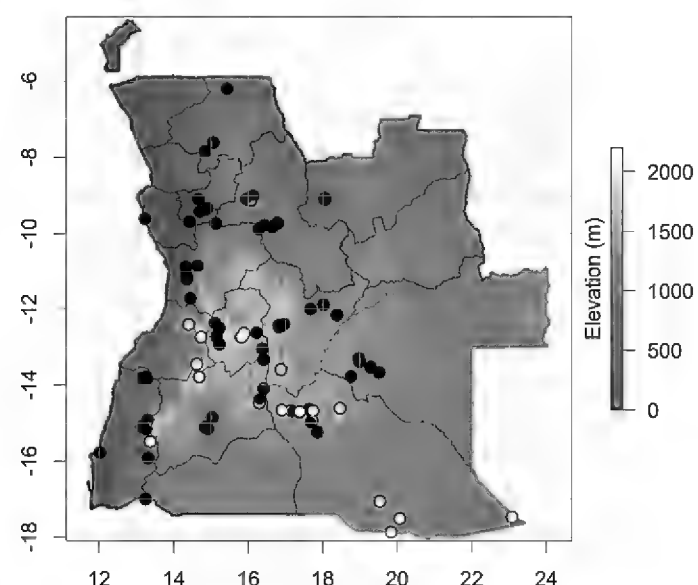
*Sclerophrys poweri* (Hewitt, 1935)

Western Olive Toad (Fig. 10; Map 9)

**Material (8 specimens):** PEM A14876–82, INBAC: WC-7076, wetland south of Lake Hundo,  $-15.01099^{\circ}$   $21.63608^{\circ}$ , 1,100 m asl. **Description:** Large robust toad; snout rounded; large elevated parotoid glands. Dorsum of females tan with distinct black-edged dark brown to deep red paired dorsal markings; in males it can be more olive-yellow; red infusions on the back of the thighs. Males with dark throat and dorsal surface spinose with



**Fig. 9.** Adult male *Sclerophrys pusilla* from Cuito town. Photo by Werner Conradie.



**Map 8.** Distribution of *Sclerophrys pusilla* in Angola.



**Fig. 10.** Adult female *Sclerophrys poweri* from Lake Hundo. Photo by Werner Conradie.

small black tipped asperites. Adult females ( $n = 3$ ) varied from 101.0–102.3 (101.8) mm (largest female: PEM A14876; maximum recorded size); adult males ( $n = 5$ ) varied from 85.5–97.0 (93.3) mm (largest male: PEM A14877; maximum recorded size). **Habitat and natural history notes:** This species was heard calling during early evenings in a flooded wetland and from margins of large natural lakes. **Comments:** Only a few records exist for southern and eastern Angola (Marques et al. 2018; Baptista et al. 2019). These specimens represent the easternmost records in Angola, and only the second record for Moxico Province (Ruas 1996).

### Hemisotidae

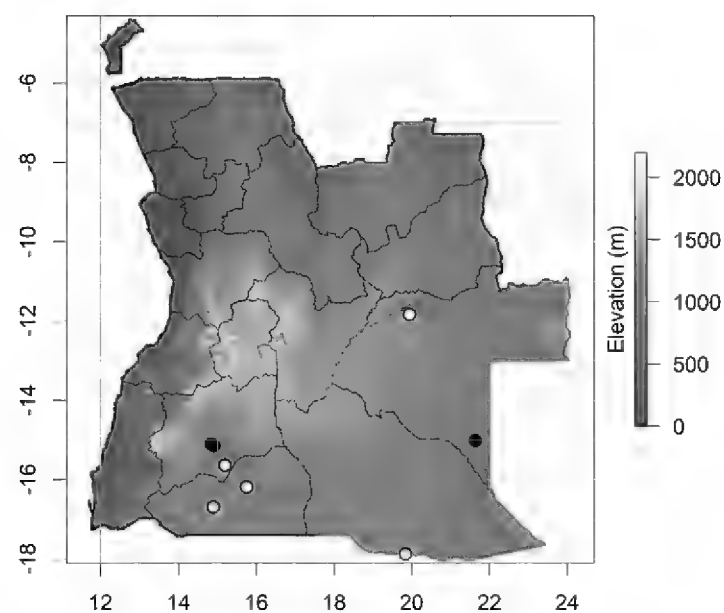
*Hemissus guineensis* Cope, 1865

Guinea Shovel-snouted Frog (Fig. 11; Map 10)

**Material (6 specimens):** PEM A14955, Cuando River, CUD2018 AC Camp 27,  $-16.09006^{\circ}$   $21.83947^{\circ}$ , 1,038 m asl; PEM A14832–3, INBAC: WC-6948, Lake Hundo,  $-14.97431^{\circ}$   $21.62966^{\circ}$ , 1,100 m asl; PEM A13831, Cuando River, camp 18,  $-14.66105^{\circ}$   $20.16858^{\circ}$ , 1,124 m asl; PEM A12771, Cuando River Source, trap 3,  $-13.00334^{\circ}$   $19.13564^{\circ}$ , 1,360 m asl. **Additional material (1 tadpole lot):** SAIAB 209095 (7

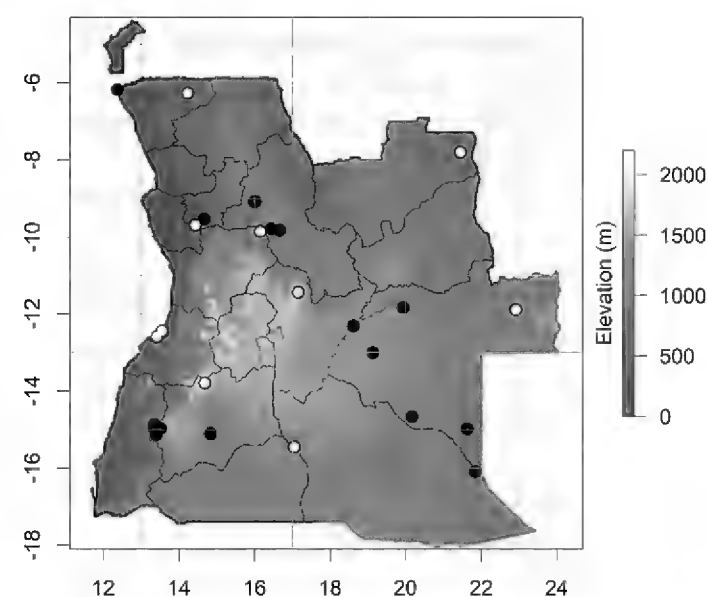


**Fig. 11.** Adult female *Hemissus guineensis* from Cuando River source. Photo by Werner Conradie.



**Map 9.** Distribution of *Sclerophrys poweri* in Angola.

tadpoles), small wooden bridge across wetland on road between Cuanavale River source camp and Munhango,  $-12.30714^{\circ}$   $18.62333^{\circ}$ , 1,397 m asl. **Description:** Small to medium sized frog; hardened pointed snout; small eyes; tympanum hidden; smooth dorsum (except PEM A12771, in which the yellow spots are slightly elevated); transverse skin ridge between posterior corners of eye, extending behind eye to above the arm; reduced webbing; large inner metatarsal and outer metacarpal tubercles. Grey dorsum with yellow mottling or spots; yellow vertebral stripe present; ventrum granular, with small irregular spots. Males with dark throats. Adult females ( $n = 3$ ) varied from 40.5–49.2 (43.4) mm (largest female: PEM A12771); adult males ( $n = 3$ ) varied from 26.7–31.6 (29.8) mm (largest male: PEM A14955). **Habitat and natural history notes:** No calls were heard. Specimens were either caught in traps or by hand while they were active at night after heavy rains in November, near open grassland and pans. One female (PEM A13831) collected in November was gravid. **Comments:** Laurent (1972) assigned all Angolan material he examined to the subspecies *H. guineensis microps*, and this was followed by Ruas (1996). However, Channing (2001) and Marques et al. (2018) documented two species of *Hemissus* occurring in Angola, *Hemissus guineensis* in the



**Map 10.** Distribution of *Hemissus guineensis* in Angola.





**Fig. 12.** Adult female *Hyperolius benguellensis* from Cubango River rapids near Fundo village. Photo by Werner Conradie.

north and *H. marmoratus* in the south-central region. We follow Laurent (1972) and assign all Angolan material to *Hemisus guineensis* until an in-depth phylogenetic work is conducted to assess the taxonomic status of the available material.

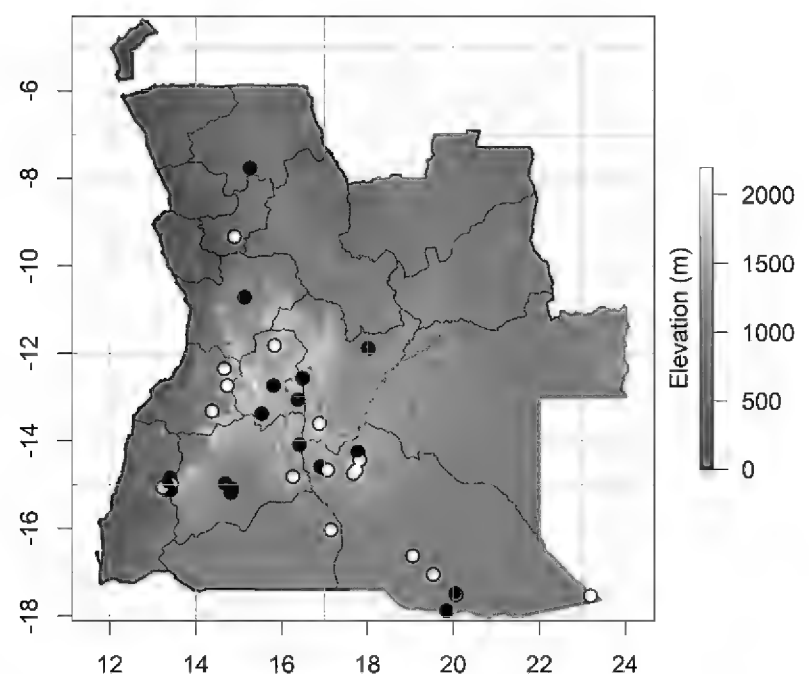
### Hyperoliidae

*Hyperolius benguellensis* (Bocage, 1893)

Benguela Reed Frog (Fig. 12; Map 11)

**Material (8 specimens, 1 tadpole lot):** PEM A12438–41, INBAC (no number x2), Cuchi River gorge, -14.59000° 16.90758°, 1,365 m asl; PEM A12661, PEM A14172, Campsite 2 near old Cuvango Mission, -13.33451° 16.41280°, 1,356 m asl; PEM A12675–6, Camp 3, Malova Village, Mipanha River, -14.09140° 16.41476°, 1,553 m asl; PEM A12666, Cubango River campsite 1 below rapids, west of Fundo village, -13.04790° 16.37896°, 1,568 m asl.

**Additional specimens (1 tadpole lot):** SAIAB 209058 (18 tadpoles), Cuvango power station, entrance to canal, -14.38650° 16.28767°, 1,457 m asl. **Description:** Small reed frog; sharp but truncated snout, with small to no anterior protrusion; pedal webbing formula: **I**(1), **II** i/e (1–0.5), **III** (1–0.5), **IV** (1–1), **V** (0.75). Dorsum green with white dorso-lateral stripes (mostly males) or uniformly green with scattered brown spots (mostly females); ventrum transparent. Males with yellow gular disc. Single adult female measured 24.7 mm (PEM A12438); adult males (n = 7) varied from 16.2–22.8 (19.7) mm (largest male: PEM A12440). **Habitat and natural history notes:** Found on margins of rivers and in wetlands. Restricted to the western side of the study area, associated with the Cubango River system. **Comments:** In the most recent revision of the *Hyperolius nasutus*-complex, 16 species have been recognized (Channing et al. 2013). At least four species are expected to occur in Angola (Channing et al. 2013; Marques et al. 2018; Baptista et al. 2019), namely *H. benguellensis*, *H. nasutus*, *H. adspersus*, and *H. dartevillei*. Two clear morphotypes exist based on the general snout shape: sharp (*benguellensis* group) and



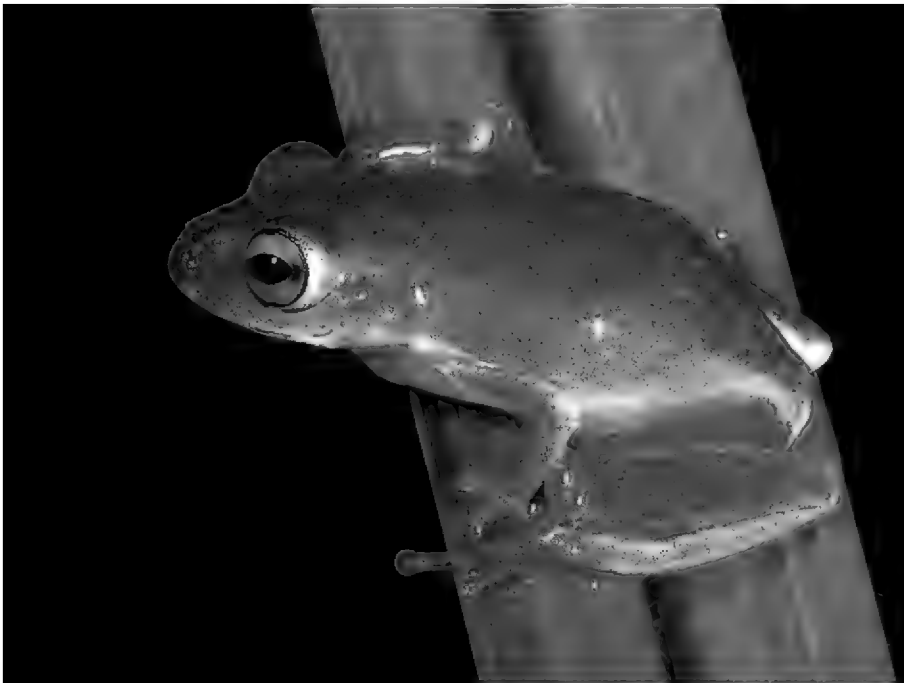
**Map 11.** Distribution of *Hyperolius benguellensis* in Angola.

rounded (*nasutus* group). Of the sharp snouted form, we distinguished between two morphotypes in southeastern Angola: the ‘shark’-like profile (*H. benguellensis*, this species account) and the acutely pointed snout, with a distinct protruding tip (*H. cf. inyangae*, see species account below). These identifications were confirmed by comparing 16S rRNA barcodes (W. Conradie, unpub. data) to published sequences (Channing et al. 2012). The remaining material is assigned to the *nasutus* group (see species account below). However, it must be noted that these little green frogs have been the subject of rigorous taxonomic debate over the years due to their cryptic nature, molecular and morphological similarity, and substantial geographic overlaps (see Channing et al. 2012 for overview). The taxonomic status of Angolan species belonging to these groups needs to be assessed in a broad-scale phylogenetic study.

*Hyperolius cinereus* Monard, 1937

Ashy Reed Frog (Fig. 13; Map 12)

**Material (12 specimens, 1 tadpole lot):** PEM A12442–4, INBAC (no numbers x 2), Cuchi River gorge, -14.59000° 16.90758°, 1,375 m asl; PEM A12664, PEM A12670, Cubango River, campsite 1 below rapids, west of Fundo village, -13.04790° 16.37806°, 1,565 m asl; PEM A13787–9, INBAC: WC-520, Dam/Hydroplant on Cuquema River, -12.42556° 16.81856°, 1,640 m asl; PEM A14128 (10 tadpoles), old Kuvango Hydroplant Site, wetland to east, -14.38755° 16.30166°, 1,438 m asl; INBAC: WC-5169, Cubango River source site, -12.66256° 16.09324°, 1,771 m asl. **Description:** Medium sized reed frog. No sexual dichromatism observed; both sexes with lime green to olive dorsum; protruding yellow eyes; red inner thighs; ventrum yellow. Males with yellow gular disc. Adult females (n = 3) varied from 20.3–29.1 (25.0) mm (largest female PEM A13789); adult males (n = 9) varied from 19.1–22.8 (21.6) mm (largest male: PEM A12443). **Habitat and natural history notes:** Only recorded from the western side of the study area, where it was associated



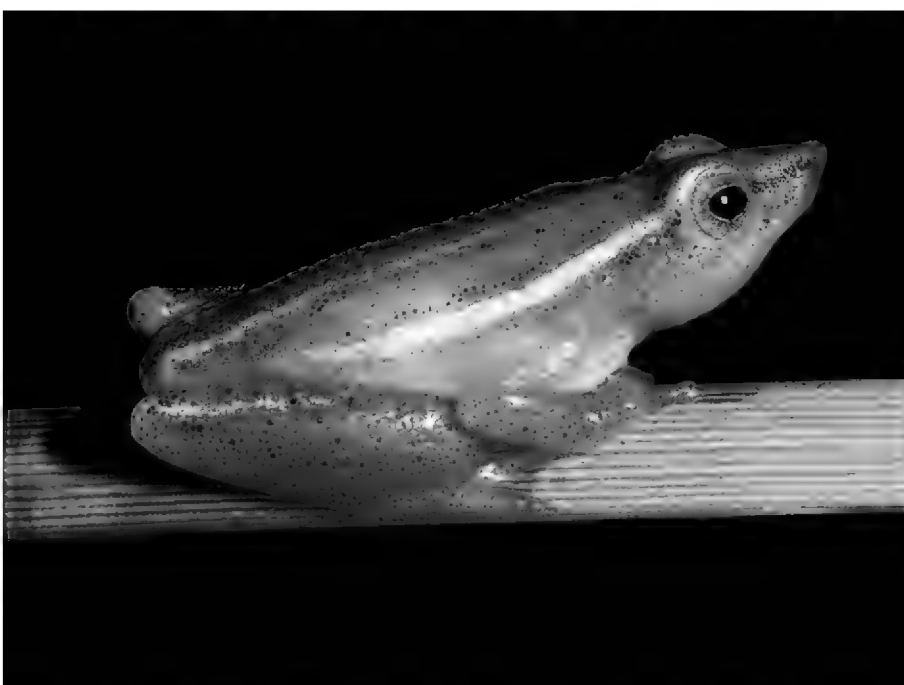
**Fig. 13.** Adult *Hyperolius cinereus* from Cubango River rapids near Fundo village. Photo by Werner Conradie.

with the Cubango and Cuito rivers. **Comments:** Widely recorded from the interior highlands of Angola (Conradie et al. 2013). The map in Marques et al. (2018) incorrectly plotted records from southern Cuando Cubango Province. The southeasternmost Angolan record of this species is close to the town of Menongue (Conradie et al. 2013).

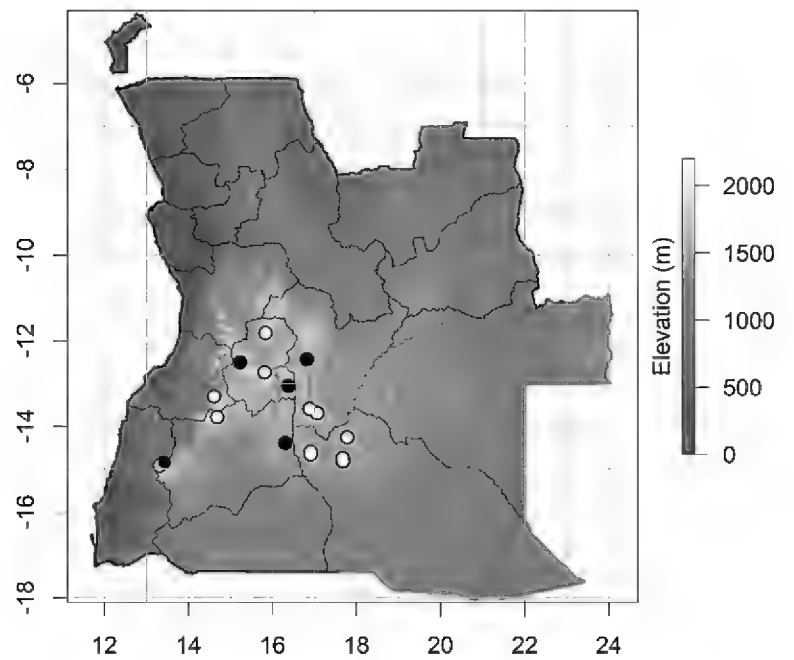
*Hyperolius* cf. *inyangae* Laurent, 1943

Nyanga Reed Frog (Fig. 14; Map 13)

**Material (30 specimens):** PEM A12730–3, INBAC: WC-4839; INBAC (no number x3), Cuando River source, -13.00346° 19.12751°, 1,353 m asl; PEM A14793–803, INBAC: WC-7023, INBAC: WC-7025, Luio River camp floodplains, -13.19711° 20.22194°, 1,181 m asl; PEM A13741, Lungwebungu River campsite, -12.58319° 18.66570°, 1,284 m asl; PEM A14887–8, Luvu River camp, -13.71200° 21.83538°, 1,082 m asl; PEM A12858–9, Quembo River source lake, -13.13624° 19.04591°, 1,366 m asl; PEM A12500, PEM A12513, river crossing before Samboano Village, -12.30700° 18.62350°, 1,398 m asl; PEM A14892–3, wetland near old quarry east of Quemba, -12.16960° 18.22965°, 1,353 m asl. **Additional material (1 specimen):** P2-

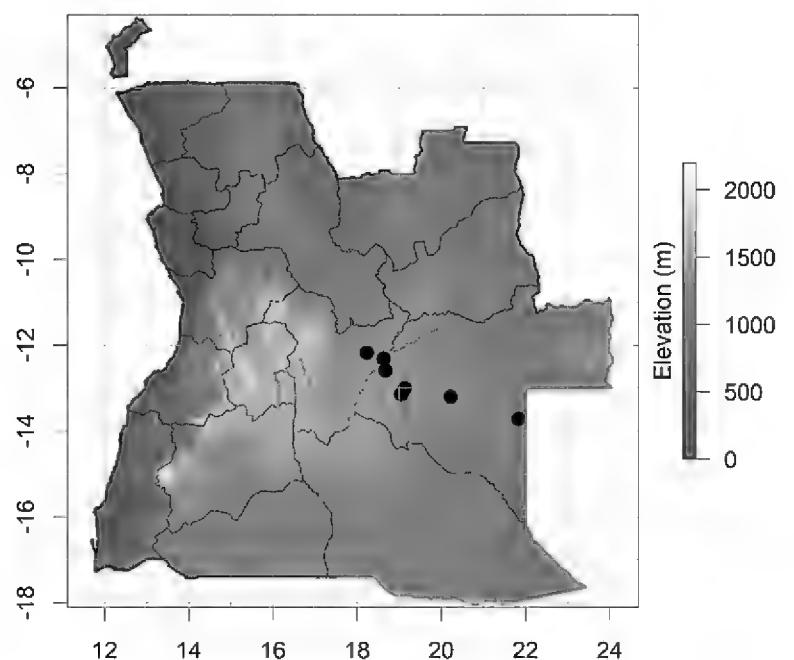


**Fig. 14.** Adult male *Hyperolius* cf. *inyangae* from Cuando River source. Photo by Werner Conradie.



**Map 12.** Distribution of *Hyperolius cinereus* in Angola.

274 (photograph and tissue sample), wetland near old quarry east of Quemba, -12.16960° 18.22965°, 1,353 m asl. **Description:** Small slender species of reed frog; very sharp snout with a small anterior protrusion, which extends well beyond the margin of the mouth; small black asperites on throat; pedal webbing formula: **I**(1), **II** i/e (1–0.75), **III** (1–0.75), **IV** (0.75–0.75), **V** (0.5). Dorsum lime green with white dorsolateral stripes; ventrum transparent; toe tips and webbing yellow. Adult females (n = 9) varied from 15.0–19.6 (16.7) mm (largest female: PEM A12500); adult males (n = 21) varied from 12.8–17.9 (15.1) mm (largest male: PEM A14893). **Habitat and natural history notes:** Found sympatric with *Hyperolius nasutus* at the Lungwebungu, Cuando, and Quembo rivers, where they were distinguished by microhabitat preference. *Hyperolius* cf. *inyangae* was found among vegetation associated with slow running water, while *H. nasutus* was found on margins of source lakes or flooded areas with larger bodies of open water. **Comments:** Bittencourt-Silva (2019) assigned a specimen from western Zambia to *H. nasutus* based on head shape and webbing, but mentioned that molecularly it is most like *H. inyangae*. The new material documented



**Map 13.** Distribution of *Hyperolius* cf. *inyangae* in Angola.

here is molecularly identical (16S rRNA: 97.5–100%) to the published sequences of *H. inyangae* (Channing et al. 2013; Bittencourt-Silva 2019) and agrees with the description, especially regarding the sharp snout usually with a pointed protrusion, but differs in the pedal webbing condition (Channing et al. 2013). It is reported to have reduced webbing and is illustrated as such, while the specimens here have more extensive webbing. This is either an error or there is a degree of variation in the webbing condition. The presence of this species so far to the west is an unexpected result, as *H. inyangae* is currently only known from the Eastern Highlands of Zimbabwe. These new records thus represent a range extension of over 1,500 km westward. Further phylogenetic work is underway to fully document the taxonomic status of this population and other species assigned to the *H. nasutus* or *H. benguellensis* complexes.

*Hyperolius nasutus* Günther, 1865

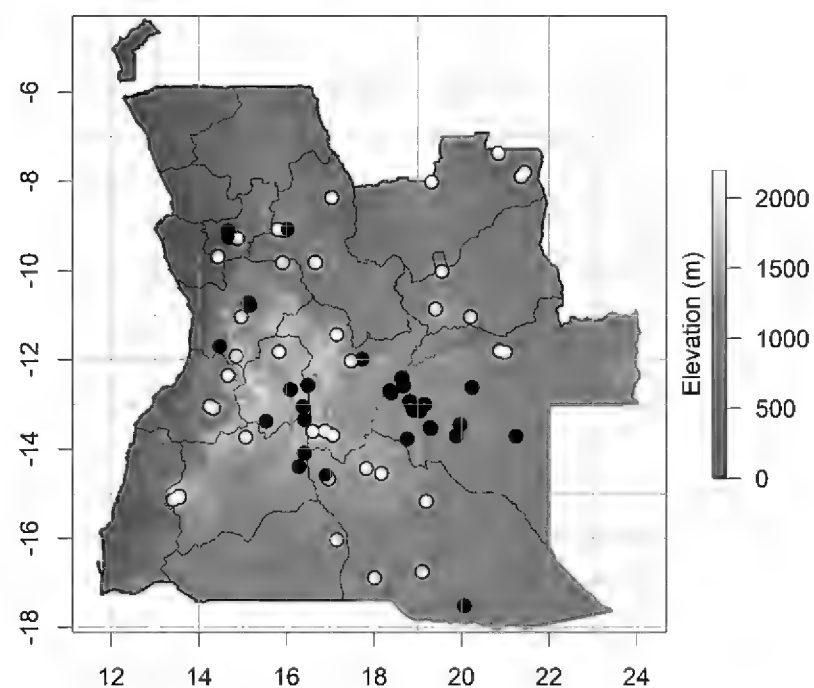
Large-nosed Reed Frog (Fig. 15; Map 14)

**Material (64 specimens, 1 tadpole lot):** PEM A12599–601, Calua River source, 6 km SE of Cuito River source, -12.73675° 18.39310°, 1,445 m asl; PEM A12424, Cunde waterfall, -13.77390° 18.75520°, 1,285 m asl; PEM A14107 (tadpoles), PEM A12435, confluence of Cuito and Calua rivers, -13.12458° 18.20909°, 1,345 m asl; PEM A12461–3, INBAC (no number x 4), Cuanavale River source lake, -13.08537° 18.89098°, 1,360 m asl; PEM A12738–40, INBAC (no number), Cuando River source, -13.00346° 19.12751°, 1,353 m asl; PEM A12693, Cubango River source site, -12.66256° 16.09324°, 1,771 m asl; PEM A12445, Cuchi River gorge, -14.5900° 16.90758°, 1,365 m asl; PEM A12550–1, Cuito River source lake, -12.68935° 18.36012°, 1,431 m asl; PEM A12427, INBAC (no number), Cuiva River bridge on EN250, -11.98345° 17.72367°, 1,267 m asl; PEM A12490, Dala River, near Samanunga village, -12.93169° 18.81458°, 1,363 m asl; PEM A12665, Cubango River campsite 1 below

rapids, west of Fundo village, -13.04790° 16.37896°, 1,568 m asl; PEM A12805–6, PEM A13804–12, Lake Tchanssengwe, -12.41402° 18.64418°, 1,393 m asl; PEM A14827–8, INBAC (no number), Luanguinga River waterfall, -13.71132° 21.24914°, 1,118 m asl; PEM A13773–80, Lungwebungu River old oxbows, -12.58129° 18.67162°, 1,304 m asl; PEM A14750–52, Quembo River right side tributary (Micongo River) past village, -13.51877° 19.28487°, 1,248 m asl; PEM A12860–62, INBAC (no number), Quembo River source lake, -13.13624° 19.04591°, 1,366 m asl; PEM A14729–35, INBAC (no number x2), Quembo River, oxbow near small waterfall, -13.54257° 19.29551°, 1,233 m asl. **Additional material (13 specimens, 8 tadpole lots):** SAIAB 209057 (1 specimen), Cuanavale River near confluence, -13.12478° 18.90017°, 1,346 m asl; SAIAB 204573 (2 specimens), Quembo River source lake, -13.13586° 19.04492°, 1,369 m asl; SAIAB 209053 (7 tadpoles), outlet River from Kuembo River source lake, -13.13689° 19.03144°, 1,392 m asl; SAIAB 209173 (3 tadpoles), Quembo River source, -13.13583° 19.04528°, 1,370 m asl; SAIAB 209051 (5 specimens), Quembo River source lake, -13.14025° 19.04822°, 1,365 m asl; SAIAB 209045 (6 tadpoles), stream outflow about 2.6 km downstream of source lake, -13.00317° 19.15153°, 1,331 m asl; SAIAB 209056 (3 specimens), SAIAB 209087 (1 specimen), small stream 3 km below Cuanavale River source camp, -13.12539° 18.89914°, 1,344 m asl; SAIAB 209049 (5 tadpoles), south west of Cambuta on main track, -13.44678° 19.96403°, 1,229 m asl; SAIAB 209055 (1 tadpole), river bridge at Cangamba, -13.69611° 19.87503°, 1,193 m asl; SAIAB 209050 (1 tadpole), Calua lagoon, -12.73600° 18.39394°, 1,448 m asl; SAIAB 209026 (1 tadpole), Cuanavale River lake outlet, -13.09414° 18.89612°, 1,357 m asl; SAIAB 209054 (4 tadpoles), Cuando River source bog, -13.00383° 19.12719°, 1,350 m asl. **Description:** Small reed frog; rounded snout. Dorsum green, with white dorso-lateral stripes and small scattered black spots;



**Fig. 15.** Adult male *Hyperolius nasutus* from Cuanavale River source. Photo by Werner Conradie.



**Map 14.** Distribution of *Hyperolius nasutus* in Angola.



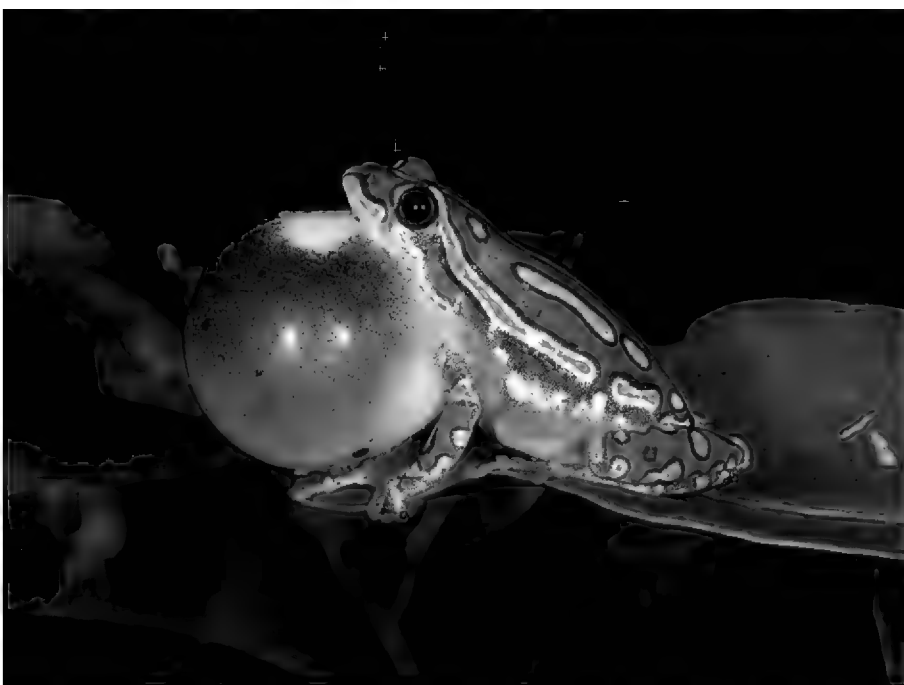
ventrum transparent; pedal webbing formula: **I**(1), **II** i/e (1–0.25), **III** (0.75–0.5), **IV** (0.75–0.5), **V** (0.5). Male throat is white. Adult females (n = 14) varied from 15.9–20.2 (18.5) mm (largest female: PEM A13810); adult males (n = 21) varied from 13.7–20.3 (17.2) mm (largest male: INBAC no number). **Habitat and natural history notes:** Found on the margins of source lakes, larger rivers, and cut-off oxbows. **Comments:** Found at certain localities in sympatry with *Hyperolius* cf. *inyangae* (see above), but can easily be distinguished based on the rounded snout and larger overall size.

*Hyperolius parallelus* Günther, 1858

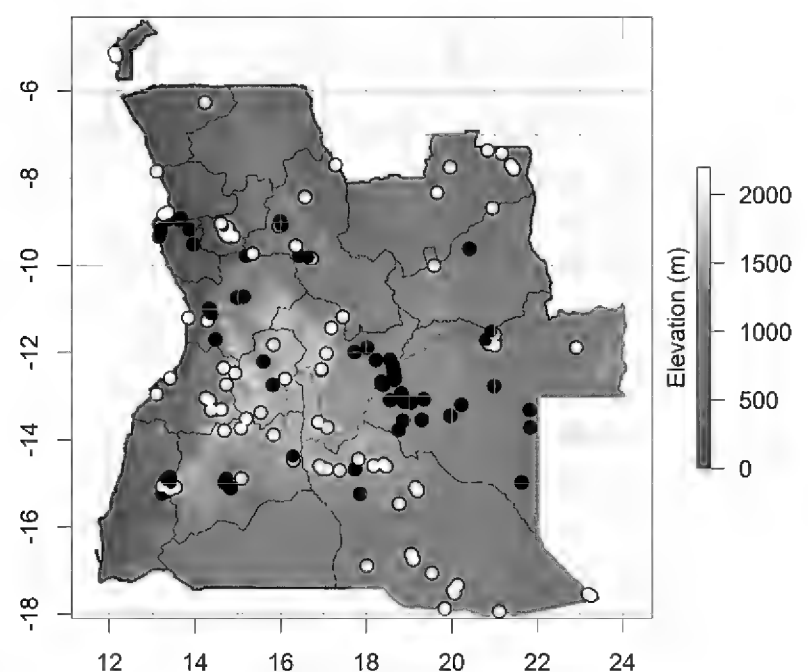
### Angolan Reed Frog (Fig. 16; Map 15)

**Material (80 specimens, 6 tadpole lots):** PEMA12436–7, INBAC (no number), Cuchi River gorge, -14.59000° 16.90758°, 1,365 m asl; PEMA12448–54, Cuanavale River source lake, -13.08537° 18.89098°, 1,360 m asl; PEMA12488, Dala River, near Samanunga village -12.93169° 18.81458°, 1,363 m asl; PEMA12525, Muhango village, -12.16310° 18.55430°, 1,430 m asl; PEMA12520, PEMA12538–42, INBAC (no number), Cuito River source lake, -12.68935° 18.36012°, 1,431 m asl; PEMA12586–91, PEMA12827, Calua River source lake, 6 km SE of Cuito River source, -12.73675° 18.39310°, 1,445 m asl; PEMA12683–4, Huambo HALO training camp, -12.73726° 15.81828°, 1,665 m asl; PEMA12851–56, INBAC: WC-4626, INBAC (no number x2), Quembo River source lake, -13.13624° 19.04591°, 1,366 m asl; PEMA13737 (tadpoles), Comba River, -12.62442° 18.65159°, 1,299 m asl; PEMA13765–6, Lungwebungu River, old oxbows, -12.58129° 18.67162°, 1,304 m asl; PEMA13794–8, PEMA13799 (tadpoles), INBAC: WC-4555, Lake Tchanssengwe, -12.41402° 18.64418°, 1,393 m asl; PEMA14097 (tadpoles), Dala River, near Samanunga village, -12.93169° 18.18146°, 1,315 m asl; PEMA14105 (tadpoles), Confluence of Cuito and Calua rivers, -13.12458° 18.89989°, 1,345 m asl; PEMA14113 (tadpoles), Cuiva River, -11.98346° 17.72841°, 1,264 m asl; PEMA14683–4, wetland near old quarry

east of Quemba, -12.16960° 18.22965°, 1,353 m asl; PEM A14698–9, wetland west of Lungwebungu River camp, -12.55855° 18.6377°, 1,308 m asl; PEM A14726, Quembo River, oxbow near small waterfall, -13.54257° 19.29551°, 1,233 m asl; PEM A14783–92, INBAC: WC-7012, INBAC: WC-7008, INBAC: WC-7014, Luio River camp floodplains, -13.19711° 20.22194°, 1,181 m asl; PEM A14834–43, INBAC: WC-6928, INBAC: WC-6928, Lake Hundo, -14.97431° 21.62966°, 1,100 m asl; PEM A14883–5, PEM A14886 (tadpoles), INBAC: WC-7083, Luvu River camp, -13.712° 21.83538°, 1,082 m asl; INBAC (no number), Cuiva River bridge on EN250, -11.98345° 17.72367°, 1,267 m asl. **Additional material (1 specimen, 14 tadpole lots):** SAIAB 204515 (9 tadpoles), below the outlet of the Cuanavale River source lake, -13.09364° 18.89597°, 1,357 m asl; SAIAB 209030 (10 tadpoles), small bridge on road to Cuanavale River source, -12.30714° 18.62333°, 1,399 m asl; SAIAB 204563 (5 tadpoles), SAIAB 204566 (1 tadpole), Quembo River source lake, -13.13611° 19.04500°, 1,367 m asl; SAIAB 209025 (1 tadpole), Quembo River source lake outlet, -13.14025° 19.04822°, 1,365 m asl; SAIAB 209027 (1 tadpole), Cunde waterfall, -13.77364° 18.75514°, 1,287 m asl; SAIAB 209065 (8 tadpoles), swamp near Cuanavale River source, -13.10750° 18.86089°, 1,386 m asl; SAIAB 209085 (1 specimen), Cuanavale River source lake, -13.08997° 18.89561°, 1,358 m asl; SAIAB 204471 (16 tadpoles), frog pan 30 km below Cuando River source camp, -13.06831° 19.34369°, 1,297 m asl; SAIAB 209024 (1 tadpole), Samununga village, -12.93228° 18.81672°, 1,364 m asl; SAIAB 209029 (3 tadpoles), south west of Cambuta on main track, -13.44678° 19.96403°, 1,229 m asl; SAIAB 209028 (4 tadpoles), Cueva River source, peat bog source, -12.66949° 18.35203°, 1,420 m asl; SAIAB 209034 (5 tadpoles), Calua River lagoon, -12.73600° 18.39394°, 1,448 m asl; SAIAB 208959 (7 tadpoles), Cuanavale River source lake outlet, -13.09414° 18.89612°, 1,357 m asl; SAIAB 209031 (6 tadpoles), Cuanavale River bog above lake, -13.08575° 18.89215°,



**Fig. 16.** Adult male *Hyperolius parallelus* from Cuanavale River source. *Photo by Werner Conradie.*



**Map 15.** Distribution of *Hyperolius parallelus* in Angola.

1,356 m asl; SAIAB 209035 (7 tadpoles), Cuvango River - Power station camp, -14.38720° 16.28760°, 1,456 m asl. **Description:** Large reed frog. Dorsal coloration varied from finely vermiculated to boldly patterned; base color mostly orange to brick red with irregular black-edged white-cream markings that were often fused to form irregular stripes, the centers of these markings exhibited a small red or yellow spot or formed a thin line; feet and webbing red; ventrum white. Adult females (n = 24) varied from 26.8–37.2 (32.2) mm (largest female: PEM A14789); adult males (n = 52) varied from 22.8–34.7 (29.2) mm (largest male: PEM A12542). **Habitat and natural history notes:** All specimens were found around larger water bodies. Males started calling in the early evening, high up in trees around the water bodies, and slowly moved to the water edge during the evening. Conradie et al. (2021) recorded predation of this species by the following species of snakes: *Crotaphopeltis hotamboeia*, *Philothamnus ornatus*, *Philothamnus semivariatus*, and *Kladirostratus acutus*. **Comments:** This species was by far the most common frog from all major waterbodies surveyed. As in the larger *viridiflavus* group, many color variations have been described in the *parallelus* subgroup (see Channing 2022). The material from this study conforms to the color pattern recorded for *Hyperolius angolensis* Steindachner, 1867, which is now a synonym of *H. parallelus*.

*Hyperolius raymondi* Conradie, Branch, and Tolley, 2013  
Raymond's Reed Frog (Fig. 17; Map 16)

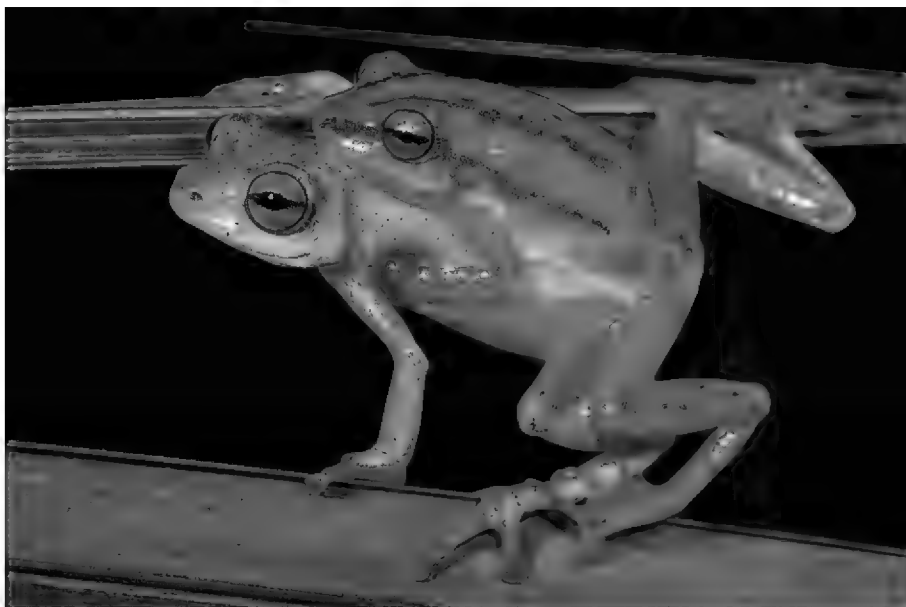
**Material (27 specimens, 3 tadpole lots):** PEM A12464–7, INBAC (no number x 2), Cuanavale River source lake, -13.08537° 18.89098°, 1,360 m asl; PEM A12514–8, river crossing before Samboano village, -12.30700° 18.62350°, 1,398 m asl; PEM A12521–2, PEM A14124 (tadpoles), Cuiva River source, -12.66825° 18.35282°, 1,407 m asl; PEM A12553–8, INBAC (no number x2), Cuito River source lake, -12.68935° 18.36012°, 1,431 m asl; PEM A12602–3, PEM A14120 (tadpoles), Calua River source lake, 6 km SE of Cuito River source, -12.73675° 18.39310°, 1,445 m asl; PEM

A12741, Cuando River source, -13.00346° 19.12751°, 1,353 m asl; PEM A12816, Cuiva River source, -12.66856° 18.35307°, 1,433 m asl; PEM A13742–3, Lungwebungu River campsite, -12.58319° 18.66573°, 1,284 m asl; PEM A14127 (tadpoles), confluence of Cuito and Calua rivers, -12.74878° 18.35433°, 1,393 m asl. **Additional material (1 specimen, 1 tadpole lot):** P2-275 (photograph and tissue sample), wetland near old quarry east of Quemba, -12.16960° 18.22965°, 1,353 m asl; SAIAB 209041 (2 tadpoles), Quembo River source lake, -13.13586° 19.04492°, 1,372 m asl. **Description:** Medium sized reed frog. Most males possess two paravertebral and two dorsolateral black stripes on lime green to olive background; three males (PEM A12515, A13742-3) did not exhibit any dorsal stripes, and in one male (PEM A12816) the stripes faded mid-dorsally and eventually disappeared. All females devoid of dorsal markings. Adult females (n = 3) varied from 21.2–23.7 (22.6) mm (largest female: PEM A12555); adult males (n = 19) varied from 16.5–21.4 (18.8) mm (largest male: PEM A12816). **Habitat and natural history notes:** Found among inundated tall grass next to slow flowing water. **Comments:** This recently described species is currently regarded as endemic to Angola, but is expected to occur in adjacent DRC (Conradie et al. 2013). Initially, it was only known from the rivers draining northwards into the Congo basin (Conradie et al. 2013), and it was therefore thought to be associated with the Congo fauna. The discovery of this species in southeastern Angola corroborates Cei's (1977) findings that the amphibian fauna located within the Cubango River system and has affinities with Congo fauna, due to the apparent lack of natural barriers between these regions. This is the southernmost record for Angola for this species, and the first from the Okavango and Zambezi River catchments.

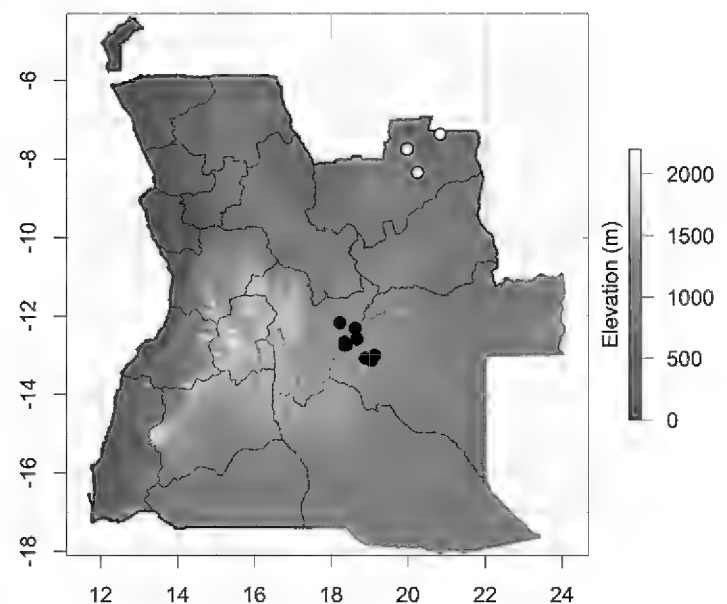
*Hyperolius quinquevittatus* Bocage, 1866

Five-striped Reed Frog (Fig. 18; Map 17)

**Material (1 specimen):** P2-273 (photograph and tissue sample only), wetland near old quarry east of Quemba, -12.16960° 18.22965°, 1,353 m asl. **Description:**



**Fig. 17.** Adult male (above) and female (below) *Hyperolius raymondi* from river crossing before Samboano village. Photo by Luke Verburgt.



**Map 16.** Distribution of *Hyperolius raymondi* in Angola.



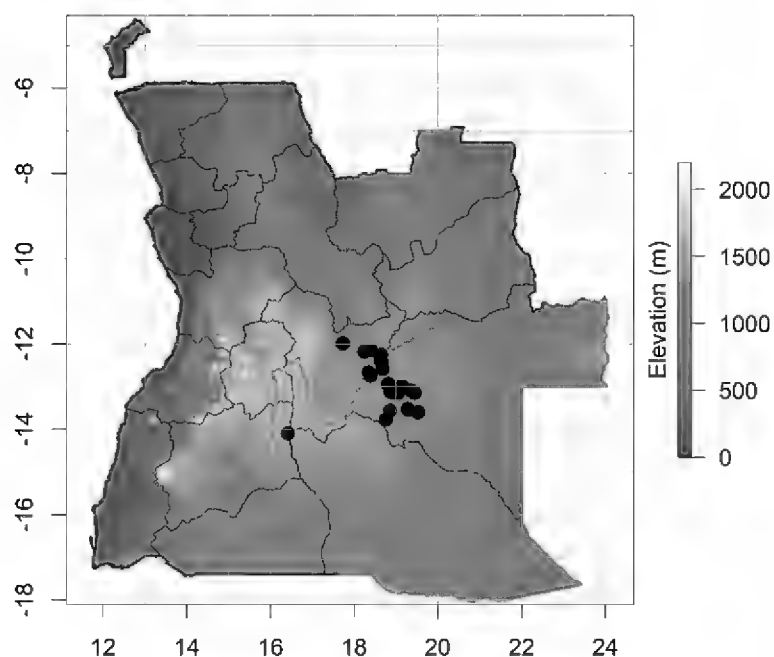
**Fig. 18.** Adult male *Hyperolius quinquevittatus* from wetland east of Quemba town. Photo by Pedro Vaz Pinto.

Medium sized reed frog; pointed snout; long slender limbs. Dorsum dark brown, with a single vertebral and two dorsolateral light green stripes. **Habitat and natural history notes:** Found in a flooded grassland, surrounded by miombo woodland. Founded syntopically with *Kassinula wittei*, *Hyperolius raymondi*, and *H. cf. inyangae*. **Comments:** This record represents an eastward range extension in Angola. It has been recorded from northwestern Zambia (Poynton and Broadley 1987, 1991; Channing 2001; Bittencourt 2019), and like *Kassinula wittei* and *Kassina kuvangensis*, this species is thus expected to occur to the north and east of the defined study area.

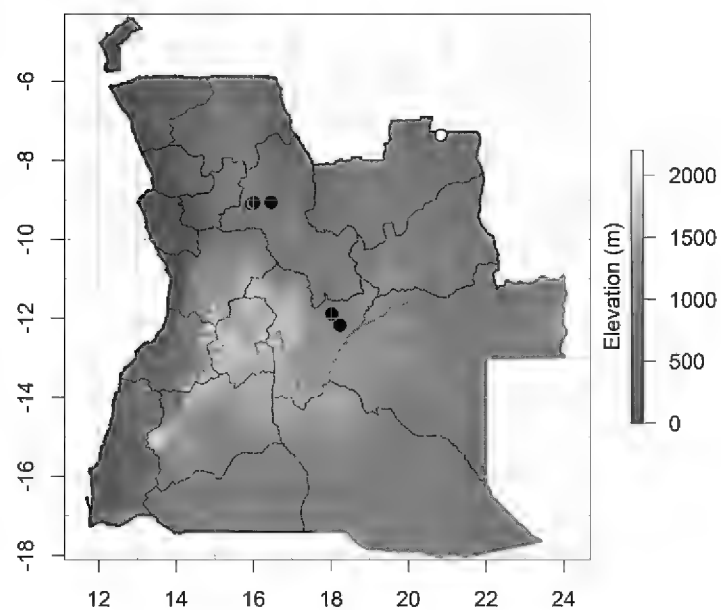
*Hyperolius* aff. *bocagei* Steindachner, 1867

Bocage's Reed Frog (Figs. 19–21; Map 18)

**Material (74 specimens, 10 tadpole lots):** PEMA12423, Cunde waterfall, -13.77390° 18.75520°, 1,287 m asl; PEM A12455–60, PEM A14085–6 (tadpoles) Cuanavale River source lake, -13.08537° 18.89098°, 1,340 m asl; PEM A12489, PEM A14098 (tadpoles), INBAC (no number), Dala River, near Samanunga village, -12.93169° 18.81458°, 1,363 m asl; PEM A12508–12, river crossing before Samboano village, -12.30700° 18.62350°, 1,397 m asl; PEM A12543–52, INBAC



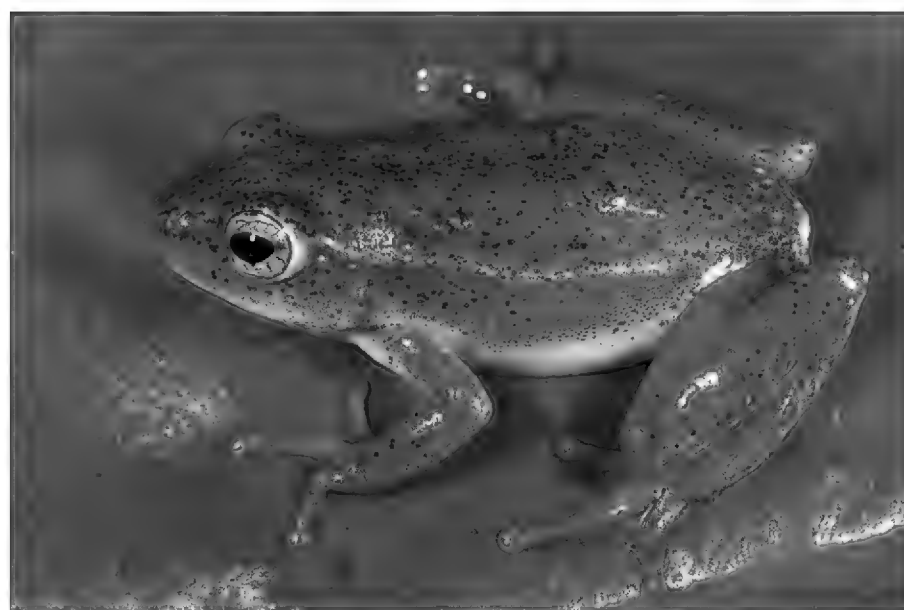
**Map 18.** Distribution of *Hyperolius* aff. *bocagei* in Angola.



**Map 17.** Distribution of *Hyperolius quinquevittatus* in Angola.



**Fig. 19.** Adult male *Hyperolius* aff. *bocagei* (green form) from Cuito River source. Photo by Werner Conradie.



**Fig. 20.** Adult male *Hyperolius* aff. *bocagei* (red form) from Cuanavale River source. Photo by Werner Conradie.



**Fig. 21.** Adult male *Hyperolius* aff. *bocagei* (brown form) from Cuito River source. Photo by Werner Conradie.



(no number x2), Cuito River source lake, -12.68935° 18.36012°, 1,431 m asl; PEM A12592–8, Calua River source lake, 6 km SE of Cuito River source, -12.73675° 18.39310°, 1,446 m asl; PEM A12619, Stop 1: road to Cuito River source, -12.25050° 18.63730°, 1,556 m asl; PEM A12674, Camp 3, Malova Village, Mipanha River, -14.09140° 16.41476°, 1,553 m asl; PEM A12734–7, INBAC: WC-4833, INBAC (no number x2), Cuando River source, -13.00346° 19.12751°, 1,553 m asl; PEM A12788–9, INBAC: WC-4614, Quembo River, source trap 2, -13.13544° 19.04397°, 1,374 m asl; PEM A14112 (tadpoles), Cuiva River, -11.98346° 17.72841°, 1,264 m asl; PEM A12815, PEM A14125 (tadpoles), Cuiva River source, -12.66856° 18.35307°, 1,407 m asl; PEM A12857, INBAC: WC-4616; INBAC (no number x5) Quembo River source lake, -13.13624° 19.04591°, 1,411 m asl; PEM A13767–72, INBAC: WC-6979 Lungwebungu River, old oxbows, -12.58129° 18.67162°, 1,304 m asl; PEM A13800–2, PEM A13803 (tadpoles), Lake Tchanssengwe, -12.41402° 18.64417°, 1,415 m asl; PEM A14090 (tadpoles), 4 km upstream from Cuanavale River source, -13.05084° 18.89726°, 1,394 m asl; PEM A14103 (tadpoles), 4 km downstream from Cuanavale River source camp, -13.11585° 18.90246°, 1,354 m asl; PEM A14106 (tadpoles), confluence of Cuito and Calua rivers, -13.12458° 18.89989°, 1,345 m asl; PEM A14686, detour route just across bridge over Cuiva River, -12.13942° 18.39393°, 1,385 m asl; PEM A14693 (tadpoles), Lungwebungu River camp, first oxbow on right side, -12.58117° 18.67106°, 1,294 m asl; PEM A14717, en route from Samanunga village to Cuanavale River source, -12.94331° 18.81118°, 1,407 m asl; PEM A14727–8, Quembo River, oxbow near small waterfall, -13.54257° 19.29551°, 1,233 m asl; PEM A14748–9, PEM A14763–65, PEM A14778, Quembo River right side tributary (Micongo River) past village, -13.51877° 19.28487°, 1,248 m asl; PEM A14757, left side tributary (Condinde River) at Cuando River bridge, -13.60076° 19.52675° 1,219 m asl. **Additional material (16 tadpole lots):** SAIAB 204553 (7 tadpoles), Cuanavale River source lake, -13.08997° 18.89389°, 1,358 m asl; SAIAB 209059 (15 tadpoles), Cuanavale River near confluence, -13.12478° 18.90017°, 1,347 m asl; SAIAB 204509 (29 tadpoles), outlet from Kuembo River source lake, -13.13689° 19.03144°, 1,375 m asl; SAIAB 204564 (25 tadpoles), SAIAB 209074 (1 tadpole), Quembo River source lake, -13.13611° 19.04500°, 1,366 m asl; SAIAB 209066 (9 tadpoles), Quembo River source lake, -13.14025° 19.04822°, 1,365 m asl; SAIAB 209062 (2 tadpoles), swamp near Cuanavale River source lake camp, -13.10750° 18.86089°, 1,386 m asl; SAIAB 204465 (19 tadpoles), Cuando River source pool, -13.00383° 19.12719°, 1,350 m asl; SAIAB 209060 (2 tadpoles), stream outflow about 2.6 km downstream of source lake, -13.00317° 19.15153°, 1,331 m asl; SAIAB 204472 (13 tadpoles), Cuando River, -13.09142° 19.35850°, 1,283 m asl; SAIAB 209067 (8 tadpoles), on Cuanavale River

road, -13.14190° 19.44503°, 1,301 m asl; SAIAB 209070 (10 tadpoles), pan near Cuanavale River camp, seepage, -13.10750° 18.86089°, 1,387 m asl; SAIAB 204569 (13 tadpoles), Samununga village, -12.93228° 18.81672°, 1,365 m asl; SAIAB 209063 (6 tadpoles), small stream 3 km below Cuanavale River source camp, -13.12539° 18.89914°, 1,344 m asl; SAIAB 209069 (11 tadpoles), pool in wetland on road edge, west of Munhango, -12.17806° 18.24306°, 1,370 m asl; SAIAB 209075 (18 tadpoles), Cuando River source bog, -13.00383° 19.12719°, 1,350 m asl. **Description:** Medium sized reed frog; rounded snout; reduced webbing; ventrum granular. Three different color forms were observed, i.e., plain light to dark green, brown, and bright red; thin dorsolateral white stripe present; small white specks on dorsal side of legs; toes and webbing red. Tadpoles with ventrum spotted and ventral blotches remain present in juveniles but fade in adults. Adult females (n = 11) varied from 16.7–21.9 (19.6) mm (largest female: PEM A12549); adult males (n = 52) varied from 14.8–21.1 (18.7) mm (largest male: PEM A12592). **Habitat and natural history notes:** Found at the margins of large rivers and source lakes within dense emergent wetland vegetation. Sympatric with other species of *Hyperolius*, mostly *H. nasutus* and *H. parallelus*. **Comments:** Initially we assigned these specimens to *H. bocagei* (NGOWP 2017), however it is generally regarded as a larger species that is associated with the *viridiflavus* group (see Schiøtz 1999). This new material differs in size (smaller) and webbing (less webbing) from *H. bocagei* (Schiøtz 1999). Phylogenetic work is currently underway to determine its taxonomic status.

*Kassina kuvangensis* (Monard, 1937)

Kuvangu Kassina (Fig. 22; Map 19)

**Material (9 specimens, 5 tadpole lots):** PEM A12496–7, unnamed side-triburaty source of Cuanavale River, -13.07518° 18.88481°, 1,374 m asl; PEM A12775–6, Quembo River, trap 4, -13.13586° 19.04709°, 1,369 m asl; PEM A12781, Quembo River trap 1, -13.13592° 19.04417°, 1,369 m asl; PEM A12825, Quembo River, trap 3, -13.13073° 19.03725°, 1,445 m asl; PEM A14116 (tadpoles), river crossing before Sombanana village, -12.30710° 18.62350°, 1,407 m asl; PEM A12828, PEM A14119 (tadpoles), Calua River source 6 km SE of Cuito River source, -12.73675° 18.39310°, 1,446 m asl; PEM A14089 (tadpoles), 4 km upstream from Cuanavale River source, -13.05084° 18.89726°, 1,394 m asl; PEM A14096, Dala River, near Samanga village, -12.93169° 18.81458°, 1,363 m asl; PEM A14101 (tadpoles), 4 km downstream from Cuanavale River source camp, -13.11585° 18.90246°, 1,354 m asl; PEM A14104 (tadpoles), confluence of Cuito and Calua rivers, -13.12458° 18.89989°, 1,345 m asl; PEM A14804, Luio River camp floodplains, -13.19711° 20.22194°, 1,181 m asl. **Additional material (4 tadpole lots):** SAIAB 209127 (1 tadpole), SAIAB 209107 (2 tadpoles), swamp

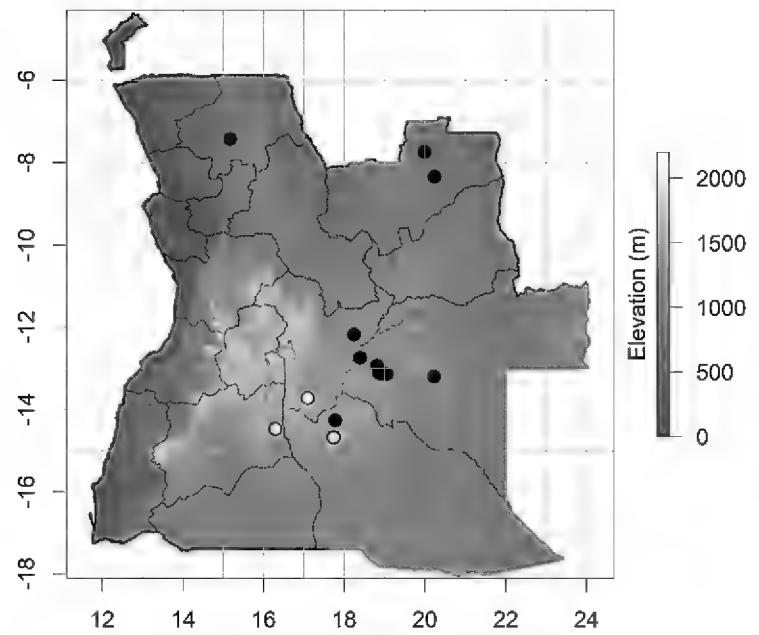


**Fig. 22.** Adult female *Kassina kuvangensis* from Cuanavale River source. Photo by Werner Conradie.

near Cuanavale River lake camp,  $-13.10750^{\circ}$   $18.86089^{\circ}$ , 1,386 m asl; SAIAB 209108 (22 tadpoles), pool in wetland on road edge west of Munhango,  $-12.17806^{\circ}$   $18.24306^{\circ}$ , 1,381 m asl; SAIAB 209089 (4 tadpoles), Calua lagoon,  $-12.73599^{\circ}$   $18.39394^{\circ}$ , 1,448 m asl. **Description:** Large sized *Kassina*; tympanum visible; elliptical vertical pupils; large inner metatarsal tubercle; subarticular tubercle well-developed. Dorsum very dark olive-brown, with scattered large darker brown yellow-edged irregular shaped spots; ventrum yellow, but in some individuals has black-edged white/yellow spots. In females, the cloaca sides are swollen. In males, the gular flap is dark and the glands behind eye/head are enlarged. Adult females ( $n = 2$ ) varied from 51.9–53.3 (52.6) mm (largest female: PEM A14096); adult males ( $n = 7$ ) varied from 38.4–52.9 (43.7) mm (largest male: PEM A12781). Tadpoles can get very large (up to 135 mm total length); LTRF 1/2(1), with strong jaw sheaths. **Habitat and natural history notes:** In the evenings, males call from the margins of source lakes and flooded areas while clinging to vegetation, and quickly submerge themselves when disturbed. **Comments:** These new records and other records from Uíge Province, which are the northwesternmost records (Ernst et al. 2020), represent the first adult *K. kuvangensis*



**Fig. 23.** Adult female *Kassina senegalensis* from Culua River source. Photo by Werner Conradie.



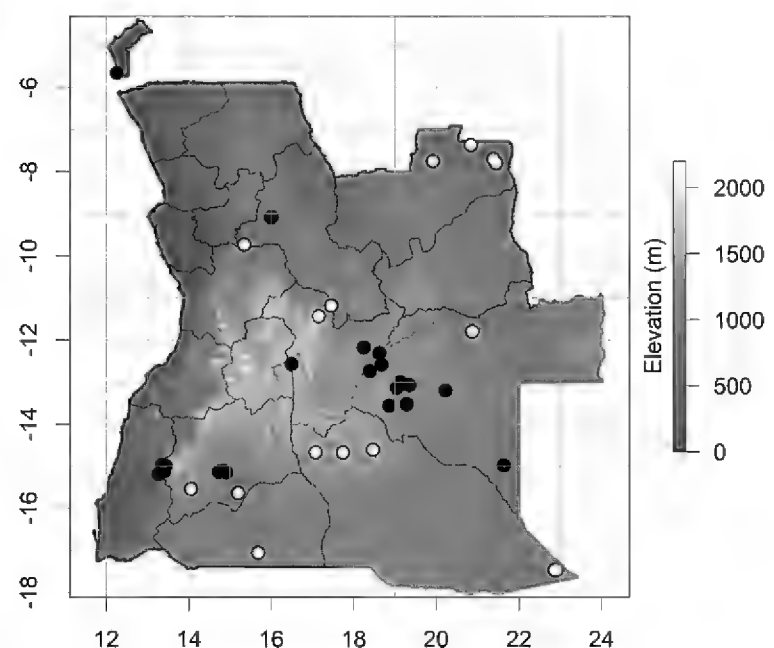
**Map 19.** Distribution of *Kassina kuvangensis* in Angola.

for Angola since the original species description (Monard 1937). The new localities recorded here lie between the species type locality in Angola (Kuvango, Monard 1937) and western Zambia (Poynton and Broadley 1987, 1991; Channing 2001).

*Kassina senegalensis* (Duméril and Bibron, 1841)

Bubbling *Kassina* (Fig. 23; Map 20)

**Material (56 specimens, 3 tadpole lots):** PEM A12604–7, Calua River source, 6 km SE of Cuito River source,  $-12.73675^{\circ}$   $18.39310^{\circ}$ , 1,445 m asl; PEM A12621, Cutata River,  $-12.56916^{\circ}$   $16.49334^{\circ}$ , 1,647 m asl; PEM A12699–700, Lungwebungu River camp bridge crossing,  $-12.58347^{\circ}$   $18.66598^{\circ}$ , 1,304 m asl; PEM A12785, Cuando River source trap 4,  $-13.00164^{\circ}$   $19.12960^{\circ}$ , 1,374 m asl; PEM A12790, Quembo River trap 2,  $-13.13544^{\circ}$   $19.04397^{\circ}$ , 1,374 m asl; PEM A12829–30, Culua River source,  $-12.73723^{\circ}$   $18.39340^{\circ}$ , 1,444 m asl; PEM A12863–9, INBAC (no number x2), Quembo River source lake,  $-13.13624^{\circ}$   $19.04591^{\circ}$ , 1,366 m asl; PEM A13744 (tadpoles), Lungwebungu River campsite,  $-12.58319^{\circ}$   $18.66573^{\circ}$ , 1,284 m asl; PEM A13757–62, INBAC: WC-6261, Lungwebungu River, trap 2,  $-12.58199^{\circ}$   $18.66562^{\circ}$ , 1,208 m asl; PEM A14094



**Map 20.** Distribution of *Kassina senegalensis* in Angola.

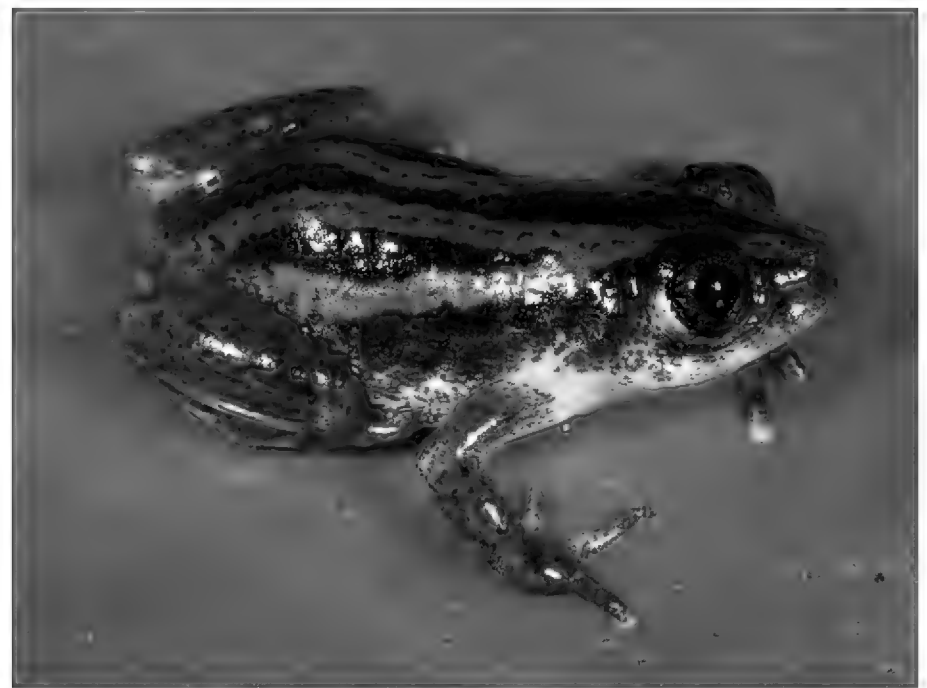
(tadpoles), series of pans south of Tempué, -13.55719° 18.85519°, 1,315 m asl; PEM A14109 (tadpoles), Cutata River, -12.56916° 16.49334°, 1,647 m asl; PEM A14687, PEM A14700, INBAC: WC-6759, Lungwebungu River camp, -12.58439° 18.66748°, 1,297 m asl; PEM A14718, PEM A14722, Quembo River bridge camp, -13.52746° 19.28060°, 1,241 m asl; PEM A14753-4, PEM A14766, Quembo River right side tributary (Micongo River) past village, -13.51877° 19.28487°, 1,248 m asl; PEM A14805-9, INBAC: WC-7017, Luio River camp floodplains, -13.19711° 20.22194°, 1,181 m asl; PEM A14844-50, PEM A14867-72, INBAC: WC-6916, INBAC: WC-6917, INBAC: WC-6953, Lake Hundo, -14.97431° 21.62966°, 1,100 m asl. **Additional material (1 tadpole lot):** SAIAB 209106 (28 tadpoles), small wooden bridge across wetland on road between Cuanavale River source camp and Munhango, -12.30714° 18.62333°, 1,399 m asl. **Description:** Medium sized *Kassina*; elliptical vertical pupils; tympanum visible. Dorsum yellow-mustard, with irregular shaped dark brown blotches, sometimes fused to form a vertebral stripe; ventrum white. In females, the cloaca is swollen, with papillae pointed downward. Male throats are black. Adult females (n = 16) varied from 27.9–41.1 (37.6) mm (largest female: INBAC: WC-6759); adult males (n = 34) varied from 35.2–43.6 (39.2) mm (largest male: PEM A14809). **Habitat and natural history notes:** This species was found in sympatry with *K. kuvangensis* in the study area, although not syntopically. *Kassina senegalensis* was found in more open habitat or sparse vegetation, calling from the edges of waterbodies, while *K. kuvangensis* was only heard calling from well-vegetated floodplains and source lakes. **Comments:** Schiøtz (1999) divided material of *K. senegalensis* into different forms, based on the dorsal markings. As pointed out by Poynton and Broadley (1987), there is considerable overlap in these color forms between and within populations. Due to the large distributional range of this species from Senegal to South Africa (Channing and Rödel 2019), spanning many different habitats and

biomes, cryptic species are expected, and this species needs a broad-scale phylogeographic study.

*Kassinula wittei* Laurent, 1940

De Witte's Clicking Frog (Figs. 24–25; Map 21)

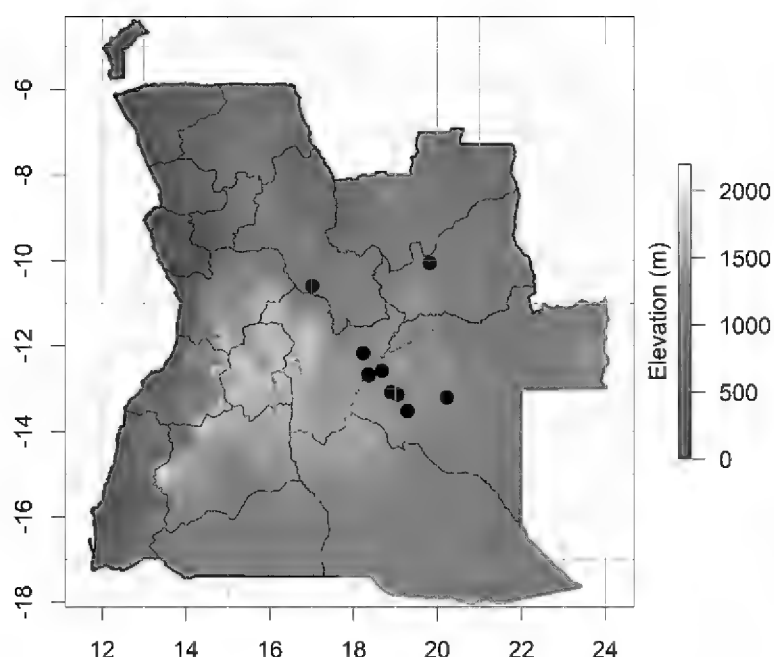
**Material (48 specimens):** PEM A12468–5, PEM A12792–3, INBAC (no number x2), Cuanavale River source lake, -13.08537° 18.89098°, 1,360 m asl; PEM A12807–12, INBAC (no number x3), Cuito River source lake, -12.68727° 18.36067°, 1,423 m asl; PEM A12817–8, Cuiva River source, -12.66856° 18.35307°, 1,433 m asl; PEM A12870–2, INBAC (no number x2), Quembo River source lake, -13.13624° 19.04591°, 1,366 m asl; PEM A14271–3, INBAC: WC-6743, Lungwebungu River camp, first oxbow on right side, -12.58117° 18.67106°, 1,294 m asl; PEM A14274–5, Cuanavale River source, -13.08537° 18.89098°, 1,357 m asl; PEM A14276–80, Quembo River right side tributary (Micongo River) past village, -13.51877° 19.28487°, 1,248 m asl; PEM A14281–4, INBAC: WC- 6958–60, Luio River camp floodplains, -13.20191° 20.22144°, 1,181 m asl; PEM A14270, PEM A14285, wetland near old quarry east of Quemba, -12.16960° 18.22965°, 1,353 m asl. **Additional material (4 specimens):** P2-278, P2-279,



**Fig. 24.** Adult male *Kassinula wittei* from Cuanavale River source. Photo by Werner Conradie.



**Fig. 25.** Adult male *Kassinula* cf. *wittei* from wetland east of Quemba town. Photo by Chad Keates.



**Map 21.** Distribution of *Kassinula wittei* in Angola.



P2-280, P2-281, wetland near old quarry east of Quemba, -12.16960° 18.22965°, 1,353 m asl. **Description:** Minute hyperoliid species. See Conradie et al. (2020b) for a detailed description of this material. The only female measured 14.7 mm (PEM A14284); adult males varied from 12.3–22.0 (14.2) mm (largest male: PEM A14270). **Habitat and natural history notes:** Found in flooded grassland and peat wetlands. **Comments:** The occurrence of this species in northeastern Angola was expected from a biogeographical point of view, but these are the first records of the species for the country. These new records extend the known range of this species from northwestern Zambia and southern DRC to central Angola by more than 400 km (see Conradie et al. 2020b). The taxonomic status of this genus has recently been validated phylogenetically and the species is considered to be closely related to *Afrixalus*, although its exact systematic placement remains unclear (see Conradie et al. 2020b; Nečas et al. 2022).

Two specimens (PEM A14270, PEM A14285) differ in the dorsal coloration pattern (vertebral band broken and no darker stipples in lighter bands versus continuous dark vertebral band and lighter bands, with fine dark stipples), maximum size (22 mm versus 16.7 mm), and potential differences in habitat preference from other *K. wittei* collected. These two specimens are similar in appearance to a specimen collected from Congolo River, Luando Strict Nature Reserve (FHK091) (see Conradie et al. 2020b). While Nečas et al. (2022) pointed out the relatively deep divergence between the specimen from Congolo River and the eastern Angolan and topotypic DRC samples, this difference was not considered in Conradie et al. (2020b). Preliminary unpublished genetic results (W. Conradie, unpub. data) show that the two specimens listed here agree genetically with the western Angolan sample (Congolo River) and may represent an undescribed cryptic species. These specimens occur syntopically with typical *K. wittei* east of Quemba, although collected from different habitats and different times of the year.



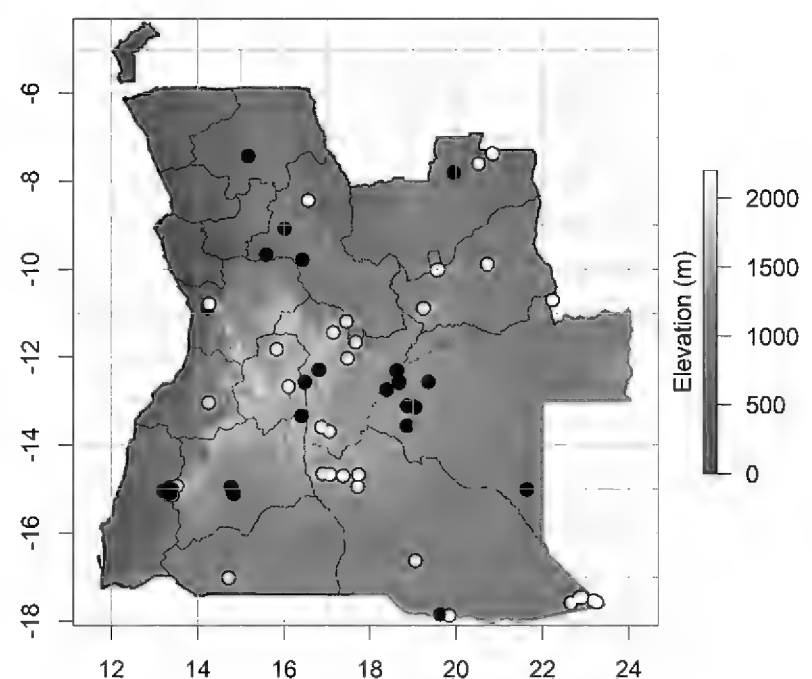
**Fig. 26.** Adult female *Phrynobatrachus mababiensis* from Cutatu River. Photo by Werner Conradie.

## Phrynobatrachidae

*Phrynobatrachus mababiensis* FitzSimons, 1932 complex

Dwarf Puddle Frog (Fig. 26; Map 22)

**Material (14 specimens, 1 tadpole lot):** PEM A12429, series of pans south of Tempué, -13.55719° 18.85519°, 1,315 m asl; PEM A12608, Calua River source, 6 km SE of Cuito River source, -12.73675° 18.39310°, 1,445 m asl; PEM A12622, Cutata River, -12.56916° 16.49334°, 1,647 m asl; PEM A12662, Campsite 2 near old Cuvango Mission, -13.33451° 16.41280°, 1,542 m asl; PEM A12688, Cubango 2017 launch site, -12.61700° 16.22133°, 1,727 m asl; PEM A12777, Quembo River source, trap 4, -13.13586° 19.04709°, 1,373 m asl; PEM A12840–1, west of Cuito town on Aludungo rd, -12.28700° 16.81716°, 1,739 m asl; PEM A12889, Quembo River source lake, -13.13624° 19.04591°, 1,366 m asl; PEM A13739, Lungwebungu River, new campsite, -12.58445° 18.66538°, 1,308 m asl; PEM A14743, Quembo River bridge camp, trap 2, -13.52816° 19.28067°, 1,240 m asl; PEM A14779, Quembo River bridge camp, trap 1, -13.52801° 19.28147°, 1,236 m asl; PEM A14873, wetland south of Lake Hundo, -15.01099° 21.63608°, 1,100 m asl; PEM A14114 (tadpoles), river before Sombanana village, -12.30710° 18.62350°, 1,407 m asl; INBAC: WC-5221, Campsite 2 near old Cuvango Mission, -13.33451° 16.41280°, 1,542 m asl. **Additional material (3 tadpole lots):** SAIAB 209079 (14 tadpoles), road to Cuanavale River camp, -12.54990° 18.67444°, 1,333 m asl; SAIAB 209105 (10 tadpoles), swamp near Cuanavale River source lake camp, 1,386 m asl; SAIAB 209111 (9 tadpoles), small wooden bridge across wetland on road between Cuanavale River source camp and Munhango, -12.30714° 18.62333°, 1,399 m asl. **Description:** Small *Phrynobatrachus*; scattered small warts present on the back; up to three and a half phalanges of longest toe free of webbing. Dorsum light brown, with scattered darker brown markings; lower lip barred in black and white; ventrum varied from immaculate to mottled



**Map 22.** Distribution of *Phrynobatrachus mababiensis* complex in Angola.

with black. Males with black throats. Adult females ( $n = 3$ ) varied from 12.8–18.0 (16.2) mm (largest female: PEM A14743); adult males ( $n = 3$ ) varied from 12.6–17.2 (14.7) mm (largest male: PEM A14779). **Habitat and natural history notes:** Found on edges of rivers and source lakes among marginal vegetation. **Comments:** Numerous cryptic species have been documented within *P. mababiensis* as currently recognized (Zimkus and Schick 2010; Zimkus et al. 2010), and the new material recorded here may represent more than one species (N. Baptista et al., unpub. data). Until further phylogenetic studies are conducted, this material is all included in the *P. mababiensis* complex.

*Phrynobatrachus natalensis* (Smith, 1849)

Snoring Puddle Frog (Fig. 27; Map 23)

**Material (20 specimens):** PEM A12637–8, Cuanavale River,  $-13.37406^{\circ}$   $18.99269^{\circ}$ , 1,297 m asl; PEM A12711, Lungwebungu River camp bridge crossing,  $-12.58347^{\circ}$   $18.66598^{\circ}$ , 1,304 m asl; PEM A12890–3, INBAC: WC-4599, INBAC (no number), Quembo River source lake,  $-13.13624^{\circ}$   $19.04591^{\circ}$ , 1,366 m asl; PEM A13738, Comba River,  $-12.62442^{\circ}$   $18.65159^{\circ}$ , 1,299 m asl; PEM A13745–8, Lungwebungu River old campsite,  $-12.58319^{\circ}$   $18.66573^{\circ}$ , 1,284 m asl; PEM A14690, PEM A14705–6, INBAC: WC-6740, Lungwebungu River camp,  $-12.58439^{\circ}$   $18.66748^{\circ}$ , 1,297 m asl; PEM A14707, wetland west of Lungwebungu River camp,  $-12.55855^{\circ}$   $18.63770^{\circ}$ , 1,308 m asl; PEM A14810–1, Luio River camp floodplains,  $-13.19711^{\circ}$   $20.22194^{\circ}$ , 1,181 m asl. **Additional material (1 specimen):** SAIAB 209104 (1 specimen), swamp near Cuanavale River source lake camp,  $-13.10750^{\circ}$   $18.86089^{\circ}$ , 1,386 m asl. **Description:** Medium sized *Phrynobatrachus*; dorsum with scattered elevated tubercles; reduced webbing; heel spine present; small outer metatarsal tubercle; large inner metatarsal tubercle; ridge running along outer toe; small tarsal ridge; mid-tarsal tubercle present; well-developed elevated subarticular tubercle. Dorsum coloration varies from grey to brown and even green; ventrum white. Female throats

are speckled, while throats of males are uniformly grey to black. Adult females ( $n = 15$ ) varied from 23.6–32.6 (28.1) mm (largest female: PEM A13745); adult males ( $n = 5$ ) varied from 26.3–30.4 (28.2) mm (largest male: PEM A14705). **Habitat and natural history notes:** Found in flooded grasslands associated with miombo woodland. **Comments:** This species is widespread in Angola (Marques et al. 2018). Although there were no records for southeastern Angola prior to Conradie et al. (2016), they are widespread east of the Zambian border (Poynton and Broadley 1985b, 1991; Channing, 2001). This is another complex within *Phrynobatrachus* containing several cryptic species, and thus deserving of further investigation (Zimkus et al. 2010; Bittencourt-Silva 2019).

## Pipidae

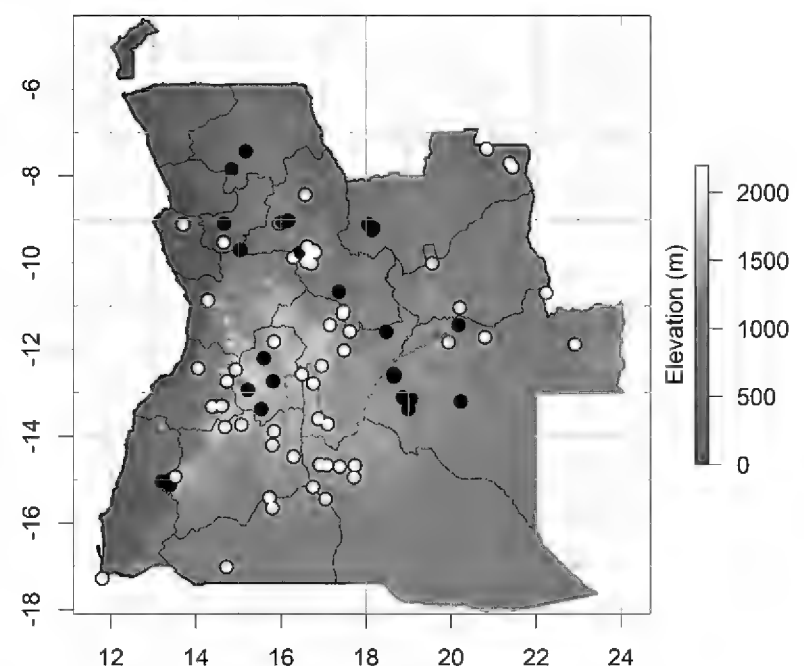
*Xenopus petersii* Bocage, 1895

Peters' Clawed Frog (Fig. 28; Map 24)

**Material (40 specimens):** PEM A11617–9, PEM A12576–84, INBAC (no number x 4), Cuito River source lake,  $-12.68935^{\circ}$   $18.36012^{\circ}$ , 1,431 m asl; PEM A12430–3, pans south of Tempue,  $-13.55719^{\circ}$   $18.85519^{\circ}$ , 1,315 m asl; PEM A12519, river crossing before Samboano village,  $-12.30700^{\circ}$   $18.62350^{\circ}$ , 1,397 m asl; PEM A12613–5, Calua River source, 6 km SE of Cuito River source,  $-12.73675^{\circ}$   $18.39310^{\circ}$ , 1,446 m asl; PEM A12634–5, roadside ditch 10 km SW of Cuito town,  $-12.44815^{\circ}$   $16.88118^{\circ}$ , 1,742 m asl; PEM A12682, Camp 3, Malova Village, Mipanha River,  $-14.09140^{\circ}$   $16.41476^{\circ}$ , 1,553 m asl; PEM A12691–2, INBAC: WC-5175, Cubango River launch site,  $-12.61700^{\circ}$   $16.22133^{\circ}$ , 1,727 m asl; PEM A12694, Cubango River source site,  $-12.66256^{\circ}$   $16.09324^{\circ}$ , 1,771 m asl; PEM A12695, INBAC: WC-5173, New dam, Kachingo,  $-12.60587^{\circ}$   $16.22003^{\circ}$ , 1,373 m asl; PEM A12697, Chicala Choloanga roadside quarry,  $-12.63611^{\circ}$   $16.04282^{\circ}$ , 1,858 m asl; PEM A12779–80, Quembo River, trap 4,  $-13.13586^{\circ}$   $19.04709^{\circ}$ , 1,373 m asl;



**Fig. 27.** Adult male *Phrynobatrachus natalensis* from Luio River. Photo by Chad Keates.

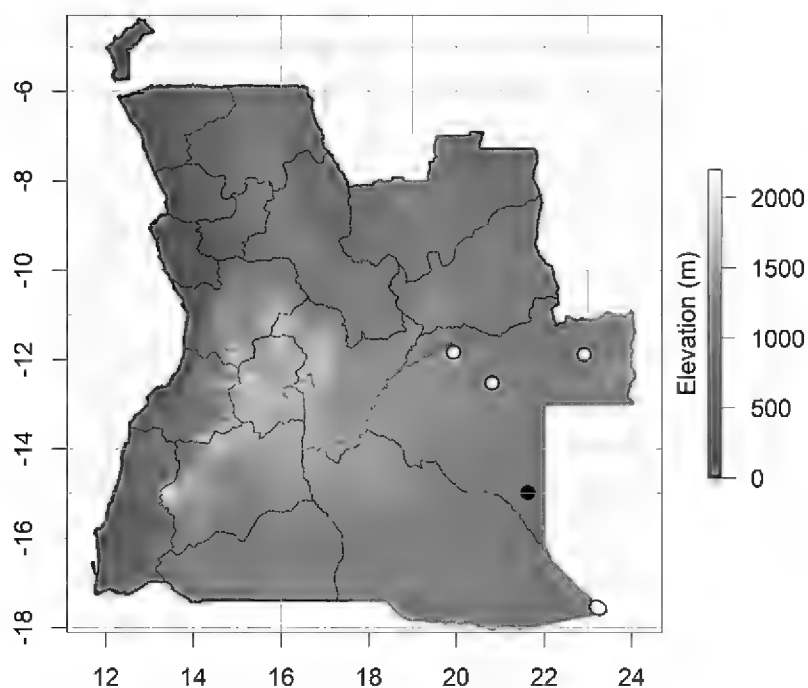


**Map 23.** Distribution of *Phrynobatrachus natalensis* in Angola.

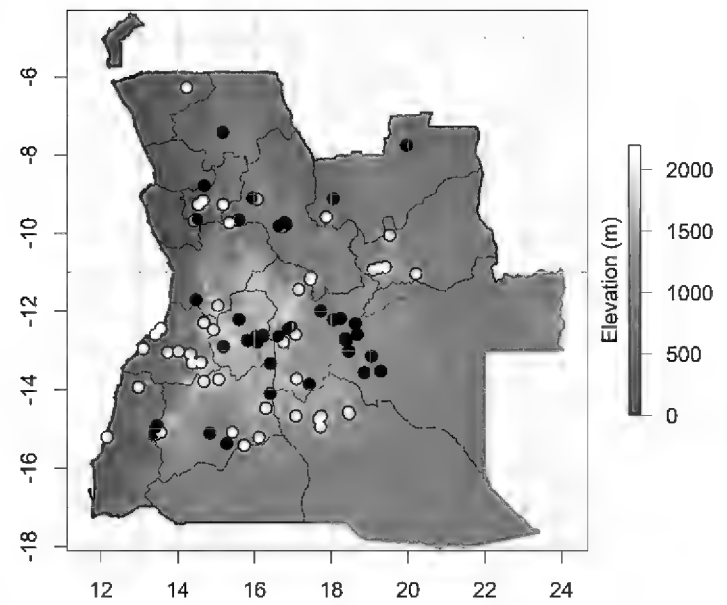


**Fig. 28.** Adult female *Xenopus petersii* from Cuito town. *Photo by Werner Conradie.*

PEM A12909, Quembo River source lake, -13.13624° 19.04591°, 1,411 m asl; PEM A13756, Lungwebungu River old campsite, -12.58319° 18.66573°, 1,284 m asl; PEM A13817, river crossing before Samboano village, -12.20672° 18.06236°, 1,387 m asl; PEM A14776, Quembo River right side tributary (Micongo River) past village, -13.51877° 19.28487°, 1,248 m asl. **Additional material (9 specimens, 1 tadpole lot):** SAIAB 204517 (1 specimen), Lungwebungu River Bridge, -12.58397° 18.66536°, 1,295 m asl; SAIAB 204468 (1 tadpole), main road bridge over upper Kwanza east of Cuito, -11.98433° 17.72197°, 1,267 m asl; SAIAB 204500 (1 specimen), small wooden bridge across wetland on road between Cuanavale source camp and Munhango, -12.30714° 18.62333°, 1,399 m asl; SAIAB 204502 (6 specimens), pool in wetland on road edge west of Munhango, -12.17806° 18.24306°, 1,370 m asl; SAIAB 209086 (1 specimen), Cuvango mission rapids camp, -13.32782° 16.41106°, 1,538 m asl. **Description:** Medium to large sized pipid; dorsum smooth; eyes on top of head; three clawed toes, no claw on prehallux; extensive webbing. Dorsum varies from light to dark brown; posterior half of ventrum and thighs with orange pigmentation. Adult females (n = 24) varied from 34.2–



**Map 25.** Distribution of *Xenopus poweri* in Angola.



**Map 24.** Distribution of *Xenopus petersii* in Angola.

74.2 (52.4) mm (largest female: PEM A12682); adult males (n = 16) varied from 37.9–51.2 (45.5) mm (largest male: PEM A11619). **Habitat and natural history notes:** Aquatic species found in all major waterbodies surveyed. **Comments:** Furman et al. (2015) split *X. petersii* and *X. poweri*, restricting the former mostly to western Angola northward to Gabon. In Angola, this species seems to be absent from the south and east, where it is replaced by *X. muelleri* and/or *X. poweri*.

*Xenopus poweri* Hewitt, 1927

### Powers' Clawed Frog (Map 25)

**Material (13 specimens):** PEM A14856–66, INBAC: WC-7040, INBAC: WC-7043, Lake Hundo, -14.97431° 21.62966°, 1,100 m asl. **Description:** Medium sized pipid; dorsum smooth; eyes on top of head; three clawed toes, no claw on prehallux; extensive webbing. Dorsum varies from light to dark brown, with scattered darker markings; ventrum grayish, with scattered darker blotches. Adult females (n = 6) varied from 55.6–65.9 (59.8) mm (largest female: PEM A14861); adult males (n = 6) varied from 43.1–51.2 (48.8) mm (largest male: PEM A14858). **Habitat and natural history notes:** After a heavy thunderstorm, numerous *X. poweri* were found moving over land away from the waterbodies. **Comments:** Only recorded from lower elevations of eastern Angola, associated with open and dry savanna. Only a limited number of records exist of this species from eastern Angola (Conradie et al. 2016; Marques et al. 2018).

## Ptychadenidae

*Ptychadena bunoderma* (Boulenger, 1907)

**Rough Ridged Frog (Fig. 29; Map 26)**

**Material (2 specimens):** PEM A12778, Quembo River source, trap 4, -13.13586° 19.04709°, 1,369 m asl; PEM A12476, Cuanavale River source lake, -13.08537° 18.89100°, 1,360 m asl. **Description:** Small stocky *Ptychadena*; dorsum warty, with no clear ridges as in other *Ptychadena* species; short stubby legs; very reduced





**Fig. 29.** Adult male *Ptychadena bunoderma* from Cuanavale River source lake. Photo by Werner Conradie.

webbing, four phalanges of the 4<sup>th</sup> toe free of webbing. Dorsum dark brown to olive, with scattered white to brown elevated tubercles; lower lip gray with white bars; back of thighs with scattered light spots. The only adult male measured 25.6 mm (PEM A12778). **Habitat and natural history notes:** Specimens were found in trap arrays (see Conradie et al. 2021) set up next to flooded areas of source lakes. They were never heard calling, and either have a very cryptic call or were not vocal during the survey periods. **Comments:** In Angola, this species is only known from the east, based on historical records (Marques et al. 2018). No new collections were made until Ernst et al. (2020) recorded a series of specimens from northwestern Angola. Elsewhere, it is known from northwestern Zambia (Channing 2001; Channing and Rödel 2019). Our new material represents a new record for southeastern Angola and the Okavango River basin.

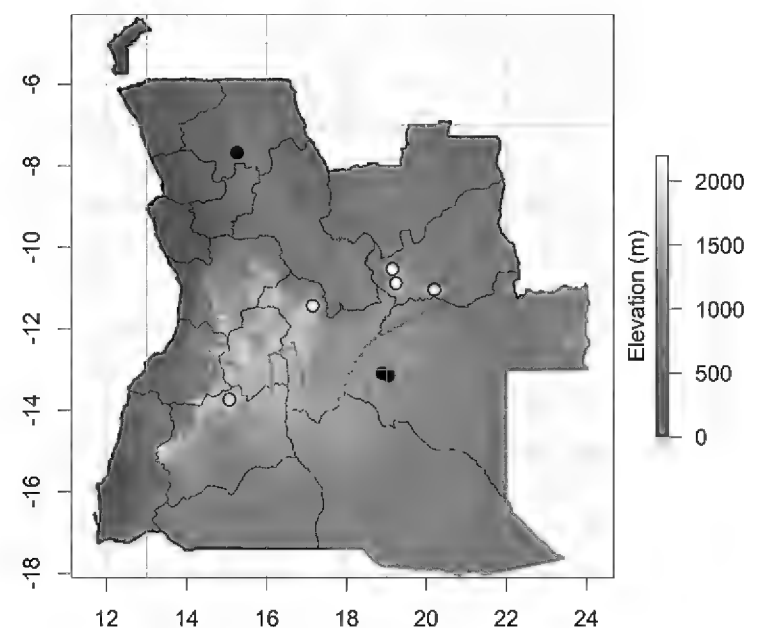
*Ptychadena grandisonae* Laurent, 1954

Many-ridged Grass Frog (Fig. 30; Map 27)

**Material (3 specimens):** PEM A12696, INBAC: WC-5185, Chicala Choloanga roadside quarry, -12.63611° 16.04282°, 1,858 m asl; PEM A12689, Cubango River launch site, -12.61700° 16.22133°, 1,727 m asl.



**Fig. 30.** Adult male *Ptychadena grandisonae* from upper Cubango River. Photo by Werner Conradie.



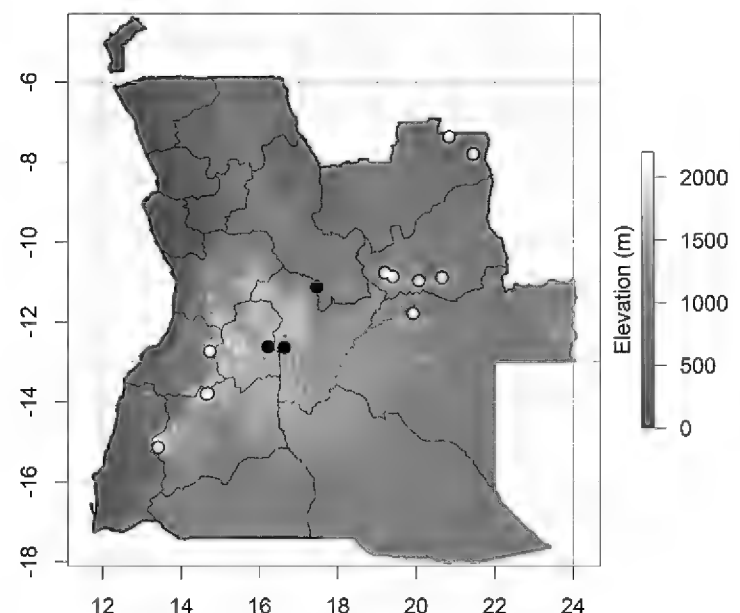
**Map 26.** Distribution of *Ptychadena bunoderma* in Angola.

**Description:** Medium sized *Ptychadena*; narrow body; ridges present on thigh; two and a half phalanges of the longest toe free of webbing. Dorsum light brown, with darker brown blotches; back of thighs with pale stripes; yellow infusion in groin. Only adult male measured 36.2 mm (PEM A12689). **Habitat and natural history notes:** This species was only encountered along the Cubango River in flooded grassland. **Comments:** The identification was based on the key provided by Poynton and Broadley (1985b) and needs genetic verification.

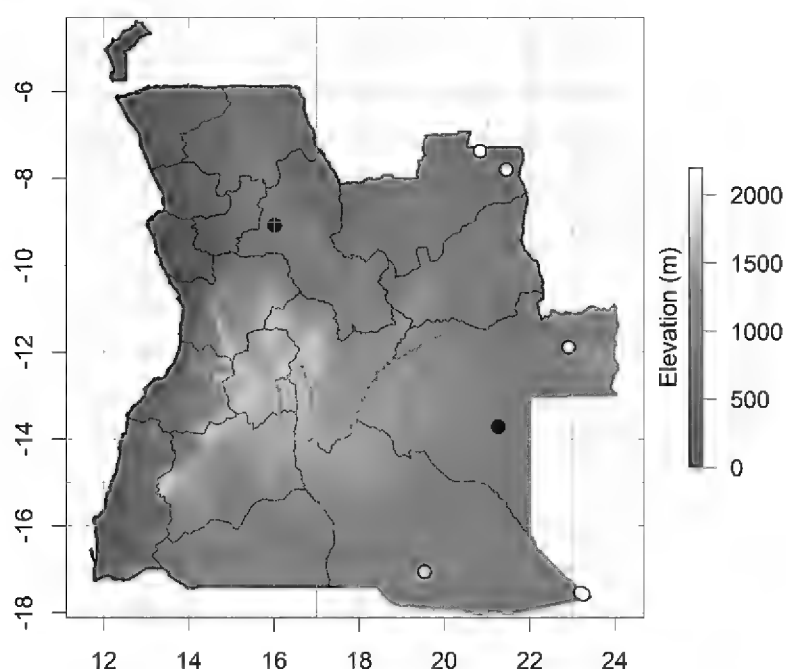
*Ptychadena upembae* (Schmidt and Inger, 1959)

Upemba Ridged Frog (Map 28)

**Material (1 specimen):** PEM A14829, camp at side tributary (Luandai River) of the Luanguinga River, -13.70885° 21.26234°, 1,116 m asl. **Description:** Medium sized *Ptychadena*; elongated body; longitudinal dorsal ridges present; long toes; reduced webbing, with up to three phalanges of longest toe free of webbing. Dorsum brown to beige with black and brown spots; black facial mask, from snout through eye to forearm; broad light vertebral band present; thin light line on dorsal tibia; back of thighs with light and dark bands; ventrum light yellow. Only adult male measured 37.7



**Map 27.** Distribution of *Ptychadena grandisonae* in Angola.



**Map 28.** Distribution of *Ptychadena upembae* in Angola.

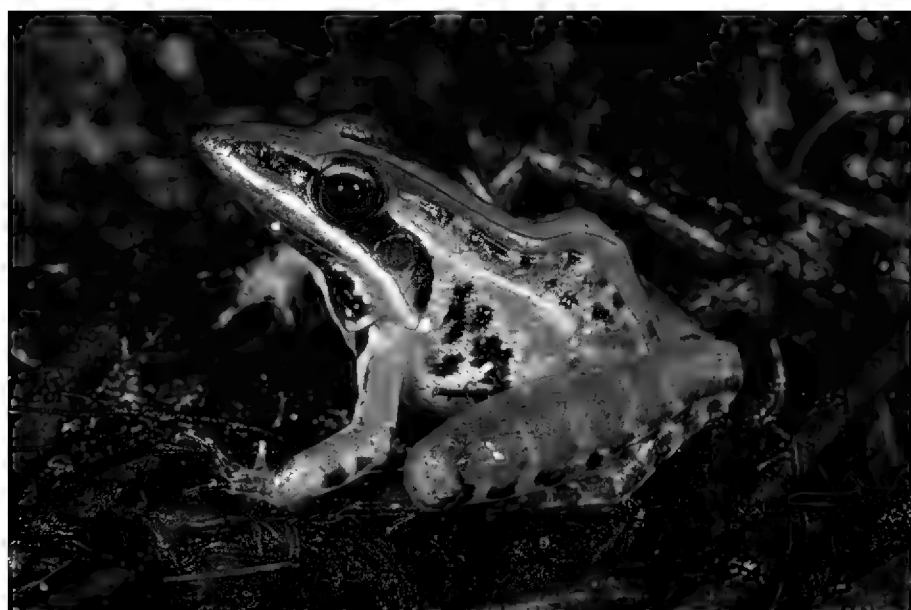
mm (PEM A14829). **Habitat and natural history notes:** Found in grassland alongside a large river during the day. **Comments:** Identification was based on the key provided by Poynton and Broadley (1985b). Only a few records of this species exist for central and eastern Angola (Marques et al. 2018). Re-examination of material recorded by Conradie et al. (2016) of *Ptychadena guibei* also conform to this species.

*Ptychadena keilingi* (Monard, 1937)

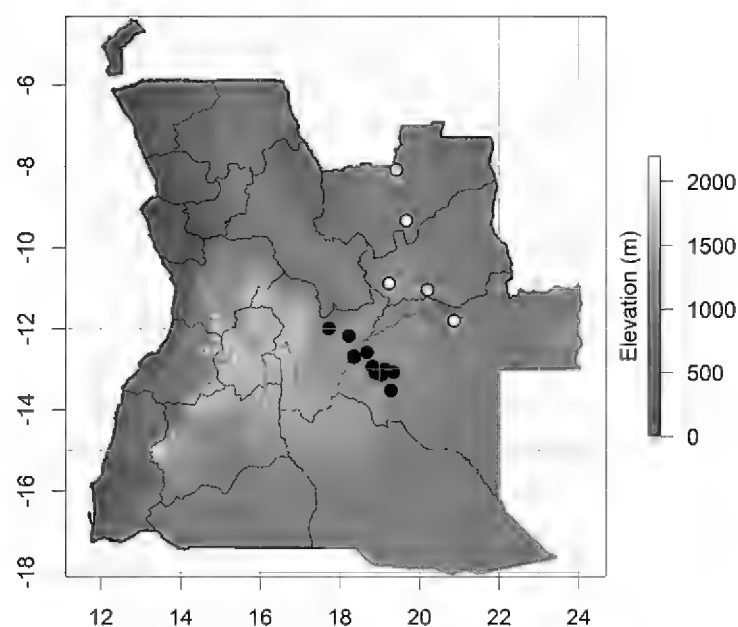
Keiling's Ridged Frog (Fig. 31; Map 29)

**Material (38 specimens):** PEM A12428, Cuiva River bridge on EN250, -11.98345° 17.72367°, 1,267 m asl; PEM A12477–8, INBAC (no number x2), Cuanavale River source lake, -13.08537° 18.89098°, 1,360 m asl; PEM A12491, Dala River, near Samanunga village, -12.93170° 18.81458°, 1,363 m asl; PEM A12559–61, Cuito River source lake, -12.68935° 18.36012°, 1,431 m asl; PEM A12646, outlet of Cuito River source lake, -12.70453° 18.35445°, 1,429 m asl; PEM A12752–9, INBAC: WC-4797, (no number x2), Cuando River source, -13.00346° 19.12751°, 1,353 m asl; PEM A12782, Quembo River, trap 1, -13.13592° 19.04417°, 1,369 m asl; PEM A12822–4, Cuiva River source, -12.66856° 18.35307°, 1,433 m

asl; PEM A12894–6, INBAC: WC-4691, INBAC: (no number x1), Quembo River source lake, -13.13624° 19.04591°, 1,366 m asl; PEM A13818–19, en route to Cuemba Village, -11.96587° 17.76176°, 1,302 m asl; PEM A14694, Lungwebungu River camp, right bank past first oxbow, -12.57956° 18.67761°, 1,295 m asl; PEM A14736, Quembo River, walk back from small waterfall, -13.52988° 19.28340°, 1,242 m asl; PEM A14780, Quembo River bridge camp, trap 1, -13.52801° 19.28147°, 1,236 m asl; PEM A14781, INBAC: WC-6962, Quembo River right side tributary (Micongo River) past village, -13.51877° 19.28487°, 1,248 m asl; PEM A14894, wetland near old quarry east of Quemba, -12.16960° 18.22965°, 1,353 m asl. **Additional specimens (2 specimens):** SAIAB 204561 (2 specimens), Quembo River source lake, -13.13611° 19.04500°, 1,367 m asl. **Description:** Medium sized *Ptychadena*; elongated body; longitudinal dorsal ridges present; rostrum protruding well beyond lower jaw and forming a very pointed and elongated keratinized protrusion; long toes; reduced webbing, with up to four phalanges of longest toe free of webbing. Dorsum colorful; red infusions on the flanks; black facial mask, from snout through eye to forearm; broad light vertebral band present; thin light line on dorsal tibia; top of thighs with light and dark bands; ventrum immaculate, with black spots on chest in some specimens; black spot in front of arm that connects with lower jaw; lower jaw with spots; back of thighs with irregular longitudinal black and yellow stripes. Adult females (n = 19) varied from 24.6–39.9 (34.8) mm (largest female: PEM A12755); adult males (n = 14) varied from 25.3–31.5 (27.9) mm (largest male: PEM A14894). **Habitat and natural history notes:** Found in the flooded margins of rivers and lakes. **Comments:** Originally described from Dala, in north-eastern Angola (Laurent 1964). It is only known from northeastern Angola (Laurent 1964; Marques et al. 2018), western Zambia (Channing 2001), and southwestern DRC (Channing and Rödel 2019). This is the southernmost record for this species, and a new species record for southeastern Angola and the Okavango River basin.



**Fig. 31.** Adult male *Ptychadena keilingi* from Cuito River source. Photo by Werner Conradie.



**Map 29.** Distribution of *Ptychadena keilingi* in Angola.



**Fig. 32.** Adult male *Ptychadena oxyrhynchus* from Cuito town. Photo by Werner Conradie.

*Ptychadena oxyrhynchus* (Smith, 1849)

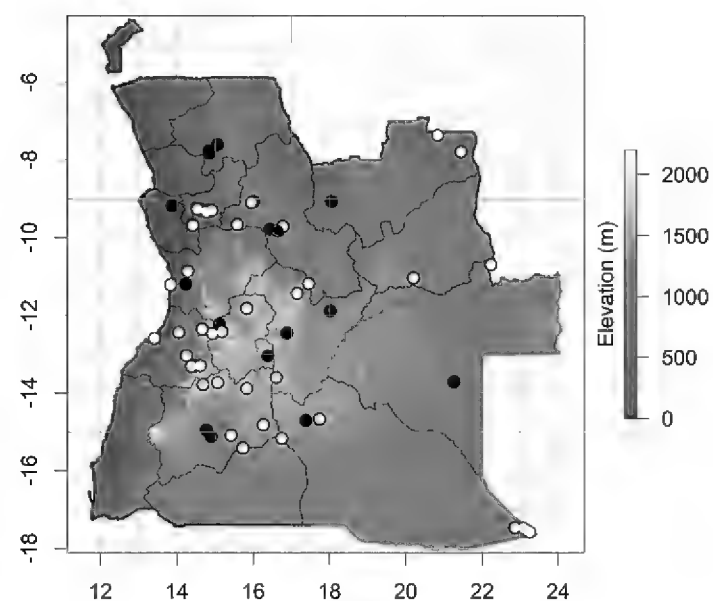
Sharp-nosed Ridged Frog (Fig. 32; Map 30)

**Material (6 specimens):** PEM A12628, roadside ditch 10 km SW of Cuito town,  $-12.44815^{\circ}$   $16.88118^{\circ}$ , 1,742 m asl; PEM A12667, Campsite 1 below Cubango River rapids, west of Fundo village,  $-13.04483^{\circ}$   $16.37520^{\circ}$ , 1,585 m asl; PEM A12835–6, 31 km W of Menongue, Cueli River,  $-14.70511^{\circ}$   $17.38014^{\circ}$ , 1,392 m asl; PEM A14830, camp at side tributary (Luandai River) of the Luanguinga River,  $-13.70885^{\circ}$   $21.26234^{\circ}$ , 1,116 m asl.

**Additional material (1 specimen):** SAIAB 204559 (1 specimen), half-way house road just outside Munhango village, pools in road. **Description:** Large and robust *Ptychadena*; sharp pointed snout; clear longitudinal dorsal ridges; extensive webbing, with one phalange on outer toe (5<sup>th</sup>) free of webbing; large pointed subarticular tubercles on toes; small inner metatarsal tubercle; outer metatarsal tubercle absent; enlarged palmar tubercles; ventrum smooth. Dorsum light brown to gray, with scattered dark spots (PEM A12628 with unusual orange dorsum and yellow infusion in the outer thigh region); pale triangle on snout; lower jaw barred; back of thigh with irregular white blotches or spots that are sometimes fused; ventrum immaculate. Adult males ( $n = 5$ ) varied from 44.1–51.9 (47.7) mm (largest male: PEM A12835).



**Fig. 33.** Adult male *Ptychadena porosissima* from Lungwebungu River crossing. Photo by Werner Conradie.



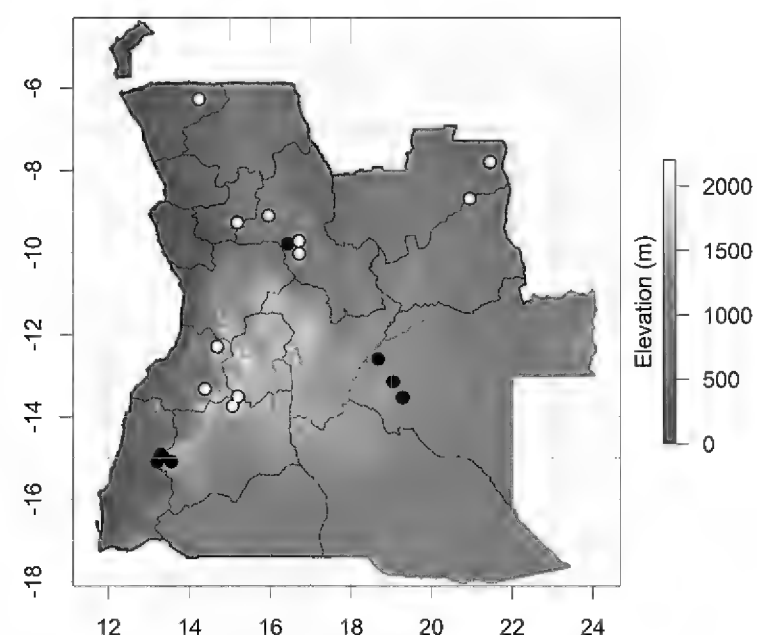
**Map 30.** Distribution of *Ptychadena oxyrhynchus* in Angola.

**Habitat and natural history notes:** Only found in open dry savanna. **Comments:** This species has a wide distribution, from Senegal to South Africa (Channing and Rödel 2019). Found across most of Angola (Marques et al. 2018), associated with a wide variety of habitats. Smith (1849) gave the type locality as ‘Kaffirland and the region of Port Natal,’ which is situated along the east coast of South Africa. Material from Angola differs molecularly from the topotypical material and warrants further phylogenetic investigation (Hübler 2015).

*Ptychadena porosissima* (Steindachner, 1867)

Striped Ridged Frog (Fig. 33; Map 31)

**Material (17 specimens):** PEM A12712–6, Lungwebungu River camp bridge crossing,  $-12.58347^{\circ}$   $18.66600^{\circ}$ , 1,304 m asl; PEM A12901–2, PEM A12906, Quembo River source lake,  $-13.13624^{\circ}$   $19.04591^{\circ}$ , 1,366 m asl; PEM A13749–51, Lungwebungu River Campsite,  $-12.58319^{\circ}$   $18.66573^{\circ}$ , 1,284 m asl; PEM A13782–3, Lungwebungu River Trap 1,  $-12.58013^{\circ}$   $18.66740^{\circ}$ , 1,298 m asl; PEM A14708–9, INBAC: WC-6750, Lungwebungu River camp,  $-12.58439^{\circ}$   $18.66748^{\circ}$ , 1,297 m asl; PEM A14782, Quembo River bridge camp,  $-13.52746^{\circ}$   $19.28060^{\circ}$ , 1,241 m asl. **Description:** Medium sized *Ptychadena*; sharp snout; large tympanum,



**Map 31.** Distribution of *Ptychadena porosissima* in Angola.



almost equal to eye diameter; three phalanges of longest toe free of webbing; webbing reaches first phalange of the outer toe; large inner metatarsal tubercle; outer metatarsal tubercle inconspicuous or absent; distinct inner tarsal ridge; subarticular tubercles single and prominent. Dorsum brown, with scattered black spots along ridges; snout paler than body; vertebral stripe broad; dorsolateral ridge pale, elevated, and prominent; white anterior bars on lower jaw; dark facial mask from snout to front of arms; dorsal pale stripe on tibia; back of thighs with light spots forming longitudinal lines; ventrum immaculate, except for scattered faint black blotches between arms. In males, ventrum covered in small brown asperites; thumbs and nuptial pads swollen. Adult females ( $n = 7$ ) varied from 34.8–46.2 (41.1) mm (largest female: PEM A12716); adult males ( $n = 7$ ) varied from 34.9–40.0 (37.4) mm (largest male: PEM A14782). **Habitat and natural history notes:** Found in flooded grasslands or river margins. **Comments:** Found in sympatry with the closely related *P. uzungwensis*, but at lower abundance. The two species can be distinguished based on ventral asperites (present in *P. porosissima* versus absent in *P. uzungwensis*), dorsal coloration (striped in *P. porosissima* versus mostly spotted in *P. uzungwensis*), and dorsal tibia line (always present in *P. porosissima* versus mostly absent in *P. uzungwensis*).

*Ptychadena subpunctata* (Bocage, 1866)  
Speckled-bellied Ridged Frog (Map 32)

**Material (2 specimens):** PEM A14874, Ninda River,  $-14.84018^\circ$   $21.66556^\circ$ , 1,081 m asl; PEM A14812, Luio River camp floodplains,  $-13.19711^\circ$   $20.22194^\circ$ , 1,181 m asl. **Description:** Large robust *Ptychadena*; snout pointed; two phalanges of longest toe free of webbing; large tympanum; small elevated inner metatarsal tubercle; outer metatarsal tubercle absent. Dorsum brown, with large rounded dark brown spots; dorsal ridges pale; narrow vertebral stripe present; lower jaw barred; white spot below eye; back of thighs with two continuous black stripes below vent from knee to knee; white stripe on dorsal tibia; ventrum finely spotted. In males, the forearms and thumbs are swollen and nuptial pads are black. Adult

males ( $n = 2$ ) varied from 44.6–61.0 (53.1) mm (largest male: PEM A14874). **Habitat and natural history notes:** Only found at Zambezi River tributaries to the east and clearly absent from the source lake area. **Comments:** Although originally described from Angola, only a few records are known from the country (Marques et al. 2018).

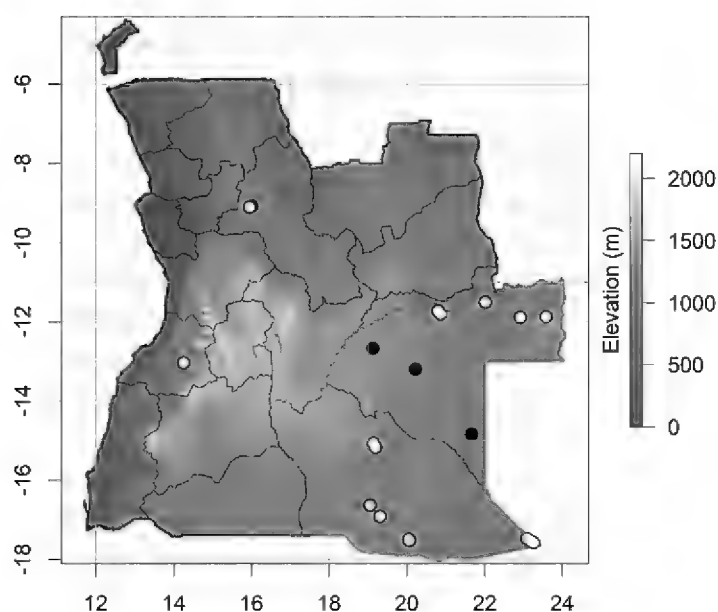
*Ptychadena taenioscelis* Laurent, 1954

Small Ridged Frog (Fig. 34; Map 33)

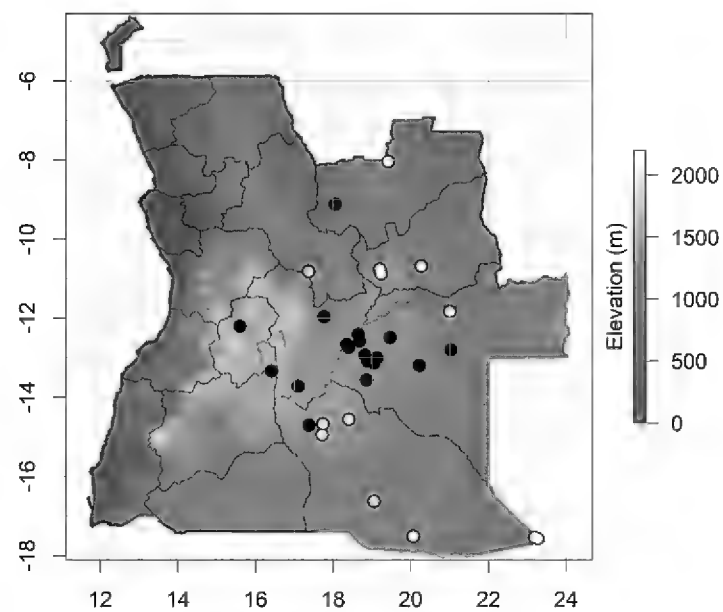
**Material (39 specimens, 2 tadpole lots):** PEM A12479–81, Cuanavale River source lake,  $-13.08537^\circ$   $18.89098^\circ$ , 1,360 m asl; PEM A12492, Dala River, near Samanunga village,  $-12.93169^\circ$   $18.81458^\circ$ , 1,371 m asl; PEM A12523, Cuiva River source,  $-12.66825^\circ$   $18.35282^\circ$ , 1,407 m asl; PEM A11609, PEM A12562–69, INBAC (no number x 4), Cuito River source lake,  $-12.68935^\circ$   $18.36012^\circ$ , 1,431 m asl; PEM A12663, Campsite 2 near old Cuvango Mission,  $-13.33451^\circ$   $16.41280^\circ$ , 1,534 m asl; PEM A12760, INBAC: WC-4750, INBAC (no number), Cuando River source,  $-13.00346^\circ$   $19.12751^\circ$ , 1,353 m asl; PEM A12767–8, Cuando River source trap 1,  $-13.00393^\circ$   $19.12808^\circ$ , 1,351 m asl; PEM A12783–4, INBAC: WC-4600, Quembo River trap 1,  $-13.13592^\circ$   $19.04417^\circ$ , 1,369 m asl; PEM A12837, 31 km W of Menongue, Cueli River,  $-14.70511^\circ$   $17.38014^\circ$ , 1,392 m asl; PEM A12897–8, INBAC (no number), Quembo



**Fig. 34.** Adult female *Ptychadena taenioscelis* from Cuito River source. Photo by Werner Conradie.



**Map 32.** Distribution of *Ptychadena subpunctata* in Angola.



**Map 33.** Distribution of *Ptychadena taenioscelis* in Angola.

River source lake,  $-13.13624^{\circ}$   $19.04591^{\circ}$ , 1,367 m asl; PEM A13813, Lake Tchanssengwe,  $-12.41403^{\circ}$   $18.64418^{\circ}$ , 1,393 m asl; PEM A13820, en route to Cuemba Village,  $-11.96587^{\circ}$   $17.76176^{\circ}$ , 1,302 m asl; PEM A14092 (tadpoles), series of pans south of Tempué,  $-13.55719^{\circ}$   $18.85519^{\circ}$ , 1,315 m asl; PEM A14122 (tadpoles), Calua River source, 6 km SE of Cuito River source,  $-12.73675^{\circ}$   $18.39310^{\circ}$ , 1,446 m asl; PEM A14691, Lungwebungu River camp, first oxbow on right side,  $-12.58117^{\circ}$   $18.67106^{\circ}$ , 1,294 m asl; PEM A14813–6, INBAC: WC-7009, Luio River camp floodplains,  $-13.19711^{\circ}$   $20.22194^{\circ}$ , 1,181 m asl. **Additional material (2 specimens, 1 tadpole lot):** SAIAB 204572 (2 specimens), Samaununga village,  $-12.93228^{\circ}$   $18.81672^{\circ}$ , 1,364 m asl; SAIAB 209102 (12 tadpoles), Calua lagoon,  $-12.73599^{\circ}$   $18.39394^{\circ}$ , 1,448 m asl. **Description:** Small *Ptychadena*; subarticular tubercles weakly developed; thin inner metatarsal tubercle; outer metatarsal tubercle absent or much reduced; three phalanges of longest toe free of webbing. Dorsum dark, with scattered black spots; broad vertebral band often present; white line above lip, from tip of snout to insertion of arm; bright green patch between eye and lip; dorsolateral ridge white; back of thighs with one continuous black stripe below vent from knee to knee; soles of feet, toes, forearms, and legs black; light line present on dorsal tibia; throat with scattered black spots; ventrum immaculate. Adult females ( $n = 21$ ) varied from 21.5–33.2 (27.4) mm (largest female: PEM A12523); adult males ( $n = 9$ ) varied from 23.1–28.2 (26.5) mm (largest male: PEM A13813). **Habitat and natural history notes:** Found along river margins and floodplains. **Comments:** The close morphological relationship between *P. pumilio* and *P. taenioscelis* has been discussed in the past, and no clear consensus has yet been reached (Perret 1979; Poynton and Broadley 1987), although the former is mostly restricted to West Africa and the latter to Southern Africa (Channing and Rödel 2019). Bittencourt-Silva (2019) alludes to the close genetic relationship between *P. pumilio* and this species. Additional investigation is needed to validate its taxonomic status.

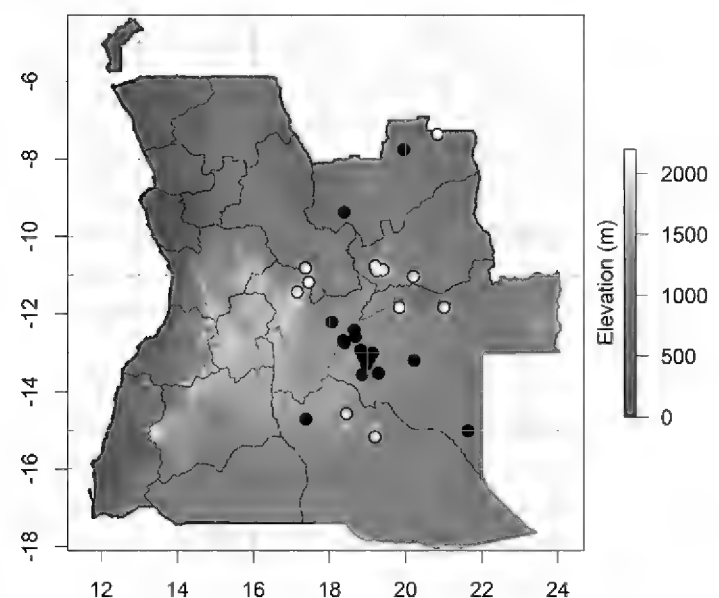


**Fig. 35.** Adult male *Ptychadena uzungwensis* from Culua River source. Photo by Werner Conradie.

*Ptychadena uzungwensis* (Loveridge, 1932)

Udzungwa Ridged Frog (Fig. 35; Map 34)

**Material (56 specimens, 7 tadpole lots):** PEM A12482–3, Cuanavale River source lake,  $-13.08537^{\circ}$   $18.89098^{\circ}$ , 1,360 m asl; PEM A12493, river crossing before Samanunga village,  $-12.93169^{\circ}$   $18.81458^{\circ}$ , 1,363 m asl; PEM A12570–2, Cuito River source lake,  $-12.68935^{\circ}$   $18.36012^{\circ}$ , 1,431 m asl; PEM A12609–11, PEM A14117 (tadpoles), Calua River source, 6 km SE of Cuito River source,  $-12.73675^{\circ}$   $18.39310^{\circ}$ , 1,445 m asl; PEM A12641, Cuanavale River,  $-13.29236^{\circ}$   $18.96283^{\circ}$ , 1,314 m asl; PEM A12717–8, Lungwebungu River camp bridge crossing,  $-12.58347^{\circ}$   $18.66598^{\circ}$ , 1,304 m asl; PEM A12761–3, Cuando River Source,  $-13.00346^{\circ}$   $19.12751^{\circ}$ , 1,353 m asl; PEM A12769, Cuando River source, trap 1,  $-13.00393^{\circ}$   $19.12808^{\circ}$ , 1,351 m asl; PEM A12813–4, Cuito River source lake,  $-12.68727^{\circ}$   $18.36067^{\circ}$ , 1,424 m asl; PEM A12826, Quembo River, trap 3,  $-13.13073^{\circ}$   $19.03725^{\circ}$ , 1,453 m asl; PEM A12831–3, Culua River source,  $-12.73723^{\circ}$   $18.39340^{\circ}$ , 1,450 m asl; PEM A12838, 31 km W of Menongue, Cueli River,  $-14.70511^{\circ}$   $17.38014^{\circ}$ , 1,392 m asl; PEM A12899–900, PEM A12903–5, Quembo River source lake,  $-13.13624^{\circ}$   $19.04591^{\circ}$ , 1,366 m asl; PEM A13752–5, Lungwebungu River campsite,  $-12.58319^{\circ}$   $18.66573^{\circ}$ , 1,284 m asl; PEM A13814, Lake Tchanssengwe,  $-12.41403^{\circ}$   $18.64418^{\circ}$ , 1,393 m asl; PEM A13816, John's crossing before village,  $-12.20672^{\circ}$   $18.06236^{\circ}$ , 1,387 m asl; PEM A14083 (tadpoles), Longa rice paddies, Longa River,  $-14.56356^{\circ}$   $18.44367^{\circ}$ , 1,277 m asl; PEM A14084 (tadpoles), Cuanavale River source,  $-13.09033^{\circ}$   $18.89396^{\circ}$ , 1,359 m asl; PEM A14087 (tadpoles), 4 km upstream from Cuanavale River source,  $-13.05084^{\circ}$   $18.89726^{\circ}$ , 1,380 m asl; PEM A14093, (tadpoles) series of pans south of Tempué village,  $-13.55719^{\circ}$   $18.85519^{\circ}$ , 1,315 m asl; PEM A14095 (tadpoles), Dala River, near Samanunga village,  $-12.93169^{\circ}$   $18.81458^{\circ}$ , 1,363 m asl; PEM A14100 (tadpoles), 4 km downstream from Cuanavale River source camp,  $-13.11585^{\circ}$   $18.90246^{\circ}$ , 1,354 m asl; PEM A14692, Lungwebungu River camp, machamba (cultivated areas) on left side of river,



**Map 34.** Distribution of *Ptychadena uzungwensis* in Angola.

-12.58276° 18.66556°, 1,295 m asl; PEM A14695, Lungwebungu River camp, right bank past first oxbow, -12.58077° 18.67585°, 1,300 m asl; PEM A14710–11, Lungwebungu River camp, -12.58439° 18.66748°, 1,297 m asl; PEM A14719, PEM A14738, Quembo River bridge camp, -13.52746° 19.28060°, 1,241 m asl; PEM A14737, Quembo River bridge camp, trap 1, -13.52801° 19.28147°, 1,236 m asl; PEM A14760, Quembo River bridge camp, trap 2, -13.52816° 19.28067°, 1,240 m asl; PEM A14817, Luio River camp floodplains, -13.19711° 20.22194°, 1,181 m asl; PEM A14875, wetland south of Lake Hundo, -15.01099° 21.63608°, 1,100 m asl. **Additional specimens (2 specimens):** SAIAB 204568 (2 specimens), Quembo River source lake, -13.13611° 19.04500°, 1,367 m asl. **Description:** Medium sized *Ptychadena*; tympanum large, three-quarters the size of the eye; small inconspicuous metatarsal tubercle; large outer metatarsal tubercle; three phalanges of longest toe free of webbing; numerous irregular-sized palmar tubercles present; prominent longitudinal ridges; outer dorsolateral ridge broken anteriorly; no ventral asperites in males. Dorsum with scattered blotches, almost forming transverse bands; lower lip barred; vertebral stripe present or absent; snout distinctly marked, without pale triangle; back of thighs with large pale blotches, almost forming longitudinal stripes; light line on dorsal tibia often absent (present in PEM A12769, 12762, and 12900). Males with swollen and dark thumbs. Adult females (n = 25) varied from 27.5–43.7 (39.0) mm (largest females: PEM A12905, PEM A12831); adult males (n = 22) varied from 30.1–39.5 (35.0) mm (largest male: PEM A12611). **Habitat and natural history notes:** Commonly found in flooded grasslands adjacent to main rivers and source lakes. **Comments:** See *P. porosissima* account for information on sympatry between these two species.

### Pyxicephalidae

*Amietia angolensis* (Bocage, 1866)

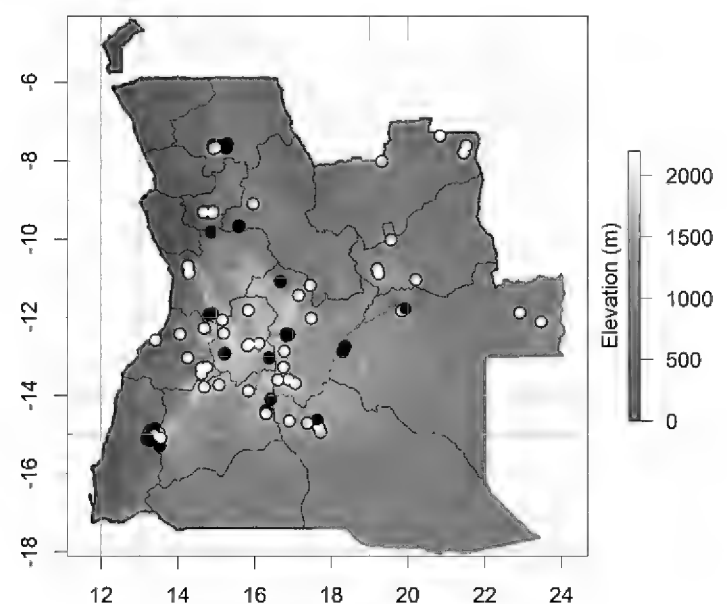
Angola River Frog (Fig. 36; Map 35)

**Material (16 specimens):** PEM A12627, roadside ditch 10 km SW of Cuito town, -12.44815° 16.88118°,

1,742 m asl; PEM A12645, confluence of Cuito and Calua rivers, -12.74878° 18.35433°, 1,413 m asl; PEM A12653–7, INBAC: WC-5245, Kuvango Hydro Plant Site, -14.38775° 16.29365°, 1,441 m asl; PEM A12669, Campsite 1 below rapids, west of Fundo village, -13.04359° 16.37439°, 1,571 m asl; PEM A12671–3, INBAC: WC-5228, Camp 3, Malova Village, Mipanha River, -14.09140° 16.41476°, 1,553 m asl; PEM A12834, 31 km W of Menongue, Cueli River, -14.70511° 17.38014°, 1,392 m asl; PEM A13785, Aquaculture farm outside Cuito, -12.43972° 16.89833°, 1,689 m asl; PEM A13786, Dam/Hydroplant on Rio Cuquema, -12.42556° 16.81856°, 1,640 m asl; PEM A14678, Villa Menongue, -14.63015° 17.63465°, 1373 m asl; bridge between Huambo and Cuito, -12.47056° 16.82389°, 1,643 m asl. **Additional material (2 specimens):** SAIAB 204011 (2 specimens), Cuchi River below bridge, -14.70272° 17.37864°, 1,393 m asl. **Description:** Large species; large tympanum, with an elevated ridge running from just behind the eye to arm; elevated paravertebral ridges continuous from behind eyes to groin, while the other ridges are broken (except in PEM A12834, where the dorsum is smooth); two and a half phalanges of longest toe free of webbing; small but conspicuous inner metatarsal tubercle; no outer metatarsal tubercle; well-developed subarticular tubercles; protruding eyes that are contained in outline of jaw viewed from below. Dorsum brown to dark green with scattered darker blotches; gular region dark with irregular white blotches that sometimes fuse to form lines; light vertebral stripe often present; dorsal tibia with dark crossbands; ventrum immaculate, except in two specimens (PEM A12654 and A12657) where the throat mottling extends onto the groin. In breeding males, the dorsum is yellowish, spiny with black-tipped asperites, and the nuptial pads on the thumbs are swollen. Adult males (n = 13) varied from 51.1–71.9 (63.9) mm (largest male: PEM A12671). **Habitat and natural history notes:** All material was found associated with the western tributaries of the Cubango River, where the substrate is rocky and the water is fast flowing. A single subadult specimen was found at the confluence of



**Fig. 36.** Adult male *Amietia angolensis* from west of Menongue. Photo by Werner Conradie.



**Map 35.** Distribution of *Amietia angolensis* in Angola.





**Fig. 37.** Adult male *Tomopterna tuberculosa* from west of Cuito town. Photo by Werner Conradie.

the Calua and Cuito rivers. This species is absent from the rivers and floodplains of the main Okavango River basin, possibly due to the sandier substrate. **Comments:** Recent phylogenetic revisions of the genus led to the identification and description of numerous cryptic species (Channing and Baptista 2013; Larson et al. 2016; Channing et al. 2016). In the process, *A. angolensis*, which was once considered to have a wide distribution across most of southern African, was restricted to Angola and is now regarded as a country endemic (Channing and Baptista 2013; Channing et al. 2016).

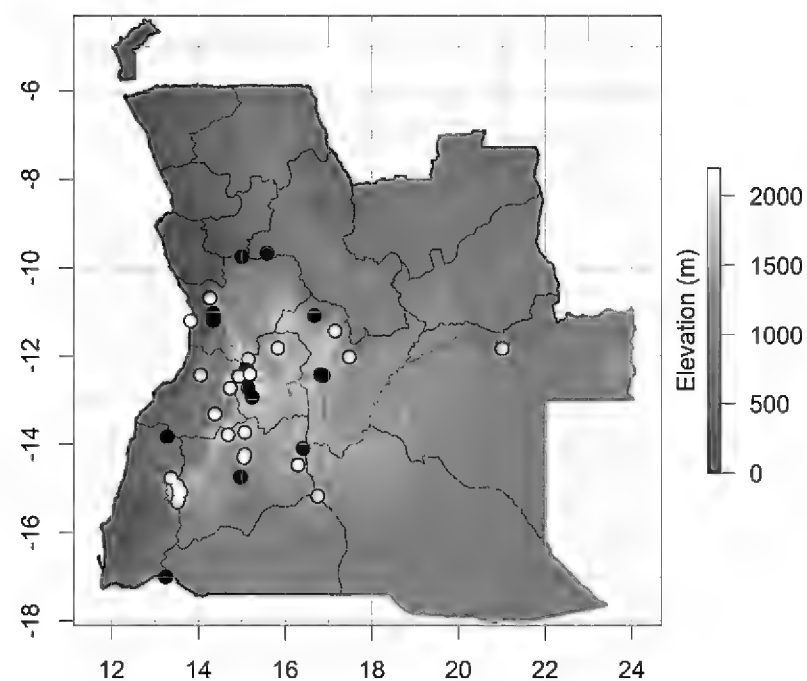
*Tomopterna tuberculosa* (Boulenger, 1882)

Rough Sand Frog (Fig. 37; Map 36)

**Material (5 specimens):** PEM A12632–3, roadside ditch 10 km SW of Cuito, -12.44815° 16.88118°, 1,743 m asl; PEM A12681, INBAC: WC-5235, Camp 3, Malova Village, Mipanha River, -14.09140° 16.41476°, 1,553 m asl; PEM A13792–3, Dam/Hydroplant on Rio Cuquema, -12.42556° 16.81856°, 1,640 m asl. **Description:** Medium sized frog; short snout; tympanum clearly visible; elevated ridge from behind eye to arm; reduced webbing; inner metatarsal tubercle large; subarticular



**Fig. 38.** Adult male *Amnirana adiscifera* stat. nov. from Cuando River source. Photo by James Harvey.



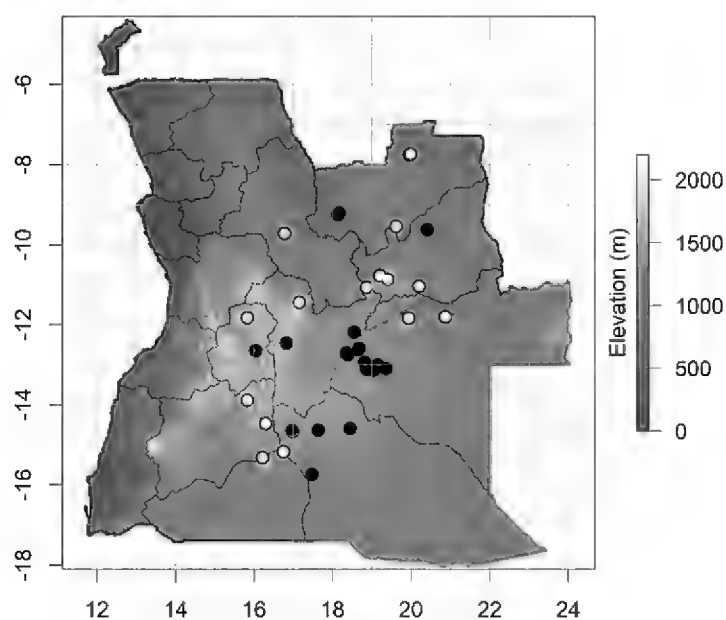
**Map 36.** Distribution of *Tomopterna tuberculosa* in Angola.

tubercles single. Dorsum brown with near-symmetrical dark brown markings with thin white border; dark brown interorbital bar; no light vertebral line. Adult females (n = 2) measured 45.4–46.3 (45.8) mm (largest female: PEM A12681); adult males (n = 4) varied from 31.9–36.5 (32.3) mm (largest male: PEM A12633). **Habitat and natural history notes:** This species was only found within the western side of the study area, associated with open and rocky habitats. **Comments:** This species occurs mostly in central and western Angola, with isolated records in the east (Marques et al. 2018). Elsewhere, it is known from northern Namibia and western Zambia to northern Tanzania and south to Zimbabwe (Channing and Rödel 2019).

## Ranidae

*Amnirana adiscifera* (Schmidt and Inger, 1959) stat. nov.  
Green White-lipped Frog (Fig. 38; Map 37)

**Material (18 specimens, 5 tadpole lots):** PEM A11599, Cuito River source lake, -12.68935° 18.36012°, 1,431 m asl; PEM A12447, Cuanavale River source lake, -13.08537° 18.89098°, 1,360 m asl; PEM A12726, Cuando River source, -13.00346° 19.12751°, 1,353 m



**Map 37.** Distribution of *Amnirana adiscifera* stat. nov. in Angola.

asl; PEM A12727–8, Cuando River source, -13.00346° 19.12751°, 1,353 m asl; PEM A12764–6, Cuando River source, trap 1, -13.00393° 19.12808°, 1,351 m asl; PEM A12791, Cuanavale River source lake camp side, -13.09442° 18.89370°, 1,368 m asl; PEM A12798–9, Cuanavale River source lake opposite side, -13.08934° 18.89485°, 1,359 m asl; PEM A12842, west of Cuito town on Aludungo road, -14.64833° 16.97444°, 1,380 m asl; PEM A13736 (tadpoles), Comba River, -12.62442° 18.65159°, 1,299 m asl; PEM A13764, Lungwebungu River old oxbows, -12.58129° 18.67162°, 1,304 m asl; PEM A14082 (tadpoles), Luissinga River, -14.58899° 18.44367°, 1,311 m asl; PEM A14091 (tadpoles), Cuanavale River source, -13.09033° 18.89396°, 1,359 m asl; PEM A14099 (tadpoles), PEM A12485–7, Dala River, near Samanga village, -12.93169° 18.81458°, 1,363 m asl; PEM A14121 (tadpoles), Culua River source, 6 km SE of Cuito River source, -12.73675° 18.39310°, 1,446 m asl; PEM A14679, Menongue, -14.63015° 17.63465°, 1,373 m asl; PEM A14716, Cuanavale River source lake, -13.09052° 18.89394°, 1,357 m asl. **Additional material (14 specimens, 4 tadpole lots):** SAIAB 209135 (5 specimens), Kalilongue Dam inflow, -12.44722° 16.82428°, 1,429 m asl; SAIAB 209081 (1 specimen), swamp near Cuanavale River source, -13.10750° 18.86089°, 1,386 m asl; SAIAB 209080 (tadpoles), Cuito River source outlet, -12.70455° 18.35203°, 1,430 m asl; SAIAB 209088 (tadpoles), Calua River lagoon, -12.73599° 18.39394°, 1,448 m asl; SAIAB 209140 (tadpoles), Cuanavale River lake outlet, -13.09414° 18.89612°, 1,357 m asl; SAIAB 204541 (tadpoles), Cuanavale River source lake below fish fence, -13.09364° 18.89597°, 1,357 m asl; SAIAB 204567 (1 specimen), Quembo River source lake, -13.13611° 19.04500°, 1,363 m asl; SAIAB 204520 (2 specimens), SAIAB 204531 (1 specimen), SAIAB 204534 (1 specimen), Cuanavale River source lake, -13.08997° 18.89389°, 1,358 m asl; SAIAB 204484 (1 specimen), stream outflow about 2.6 km downstream of Cuando River source lake, -13.00317° 19.15153°, 1,333 m asl; SAIAB 204496 (2 specimens), river at Munhango lagoon, -12.17281° 18.54897°, 1,376 m asl. **Description:** Large ranid; large tympanum, nearly equal in size to eye; elevated upper lip ridge from snout tip to above arm; pair of dorsolateral ridges from eye to urostyle; some specimens have a small flap or ridge above the vent; smooth elevated subarticular tubercles on feet; small indistinct outer metatarsal tubercle, inner metatarsal tubercle present; pedal webbing formula: **I** (1), **II** i/e (1-2), **III** i/e (1-3), **IV** (2-3), **V** (1); no dilated toe tips or terminal discs, no horizontal grooves present on toe tips; no external vocal sacs. All the adults collected were green and not the typical golden-brown coloration as illustrated in Du Preez and Carruthers (2009). Metamorphs retain dorsal and ventral spots, which fade during growth. Tadpoles are orange with black scattered dots. Males with a small nuptial pad on the thumb and enlarged glands on the upper arm. Adult

females (n = 7) varied from 57.0–66.5 (61.6) mm (largest female: PEM A14716); adult males (n = 6) varied from 46.9–62.4 (55.0) mm (largest male: PEM A12799). **Habitat and natural history notes:** Males called in late afternoons and early evenings, from vegetation on the edge of open deep waters. **Comments:** Currently, five species of *Amnirana* have been recorded from Angola (Marques et al. 2018; Baptista et al. 2019): *A. albolabris*, *A. darlingi*, *A. lemairei*, *A. lepus*, and *A. parkeriana*. All except *A. darlingi* are forest-associated species, with toes that are dilated or have discs with horizontal grooves. The specimens found in our study do not exhibit dilated toes or terminal discs. Five specimens from Chitau that were initially referred to as *Rana albolabris* (see Schmidt 1936), were later described as *Rana albolabris adiscifera* by Schmidt and Inger (1959). Those authors only compared it to *R. albolabris* and *R. a. lemairei*, and differentiated it based on the condition of the toes (no dilated tips or discs), webbing (reduced versus extensive) and foot length (long versus short), respectively. Later, without much explanation, Laurent (1964) synonymised it with *Rana darlingi* [= *Amnirana darlingi*], and this was followed by Poynton (1964) and Perret (1977). Jongsma et al. (2018) showed that eastern (Malawi) and western (Angolan) *A. darlingi* material differ significantly enough on a molecular level to warrant taxonomic re-evaluation. However, no taxonomic action has been undertaken pending more evidence. The type locality of *A. darlingi* is ‘Mazöe and between Umtali [Mutare] and Marandellas [= Marondera], Mashonaland, Zimbabwe’ and represents the eastern material of Jongsma et al. (2018). The new series of specimens is in full morphological agreement with the description of *R. a. adiscifera*. However, no coloration details were provided in the original description or in Schmidt (1933). The newly collected material agrees in preserved coloration and morphology to photos of the holotype (<https://collections-zoology.fieldmuseum.org/catalogue/1848393>). The green Angolan form of *A. darlingi* is also in agreement with the green ‘undescribed Hillwood frog’ referred to by Channing (2001) and Channing and Rödel (2019). Recently, Ceríaco et al. (2016, 2018) also documented this green form of *A. darlingi* from central Angola. Based on the color differences, together with the typical form (green versus brown) and the genetic results by Jongsma et al. (2018), we here formally assign the green western material to Schmidt and Inger’s (1959) *adiscifera* and elevate it to full species, *Amnirana adiscifera* **stat. nov.** This species is widely distributed in central Angola and northwestern Zambia (see Channing 2001; Channing et al. 2013; Marques et al. 2018; Channing and Rödel 2019). Similar distribution patterns have been observed in *Kassinula wittei*, *Kassina kuvangensis*, as well as the snake *Limnophis bicolor* (Conradie et al. 2020a,b; this study). *Amnirana* can be divided into two morphotypes: those with short feet, dilated toes, or terminal discs and extensive webbing

(*albolabris*, *amnicola*, *asperrima*, *fonensis*, *lemairei*, *lepus*, *occidentalis*, and *parkeriana*), and those with long feet, reduced webbing, and no dilated toes or discs (*adiscifera*, *darlingi*, and *galamensis*). The former group is restricted to forests, while the latter prefers flooded grasslands in savanna (Poynton 1964). However, this pattern is not mirrored in the phylogenetic analysis, and indicates that adaptation from savanna to forest has occurred more than once (Jongsma et al. 2018).

## Discussion

The material collected during this study contributes substantially to the knowledge of Angolan amphibians. Our findings have increased the number of documented amphibians for Angola by at least five species, three of which are potentially new (i.e., *Hyperolius* aff. *bocagei*, *Kassinula* cf. *wittei*, and *Leptopelis* sp.). A large collection of the green *Amnirana* ‘*darlingi*’ allowed us to reassess the taxonomic status of this material and led to both the reinstatement of Schmidt and Inger’s (1959) *adiscifera* and its elevation to full species as *Amnirana adiscifera* **stat. nov.** The rain frogs (*Breviceps* sp.) collected represent the first modern (post civil unrest, ~2002) material for Angola, and allowed us to explore their taxonomic status, which led to the description of a new endemic species, *Breviceps ombelanonga* (see Nielsen et al. 2020). Furthermore, the *Kassinula wittei* specimens represent the first country records, a range extension of over 500 km, and further allowed us to revisit the taxonomic relationships of the group relative to other hyperoliids (Conradie et al. 2020b). Conradie et al. (2020b) and Nielsen et al. (2020) highlighted the relevance of these new collections on the national and continental levels, as well as the necessity for further studies to document the diversity and distribution of Angolan biodiversity.

Some of the species recorded here at the headwaters of the Okavango (e.g., *Amnirana adiscifera* **stat. nov.**, *Kassinula wittei*, and *Kassina kuvangensis*) also occur in northwestern Zambia and eastern DRC (Poynton and Broadley 1985a,b, 1987, 1988; Channing 2001). Cei (1977) suggested that the amphibian fauna located south of the main Congo rivers to the Cubango rivers should have close affinities, given the lack of natural barriers. The limited genetic differences between *Kassinula wittei* from Angola and DRC (Nečas et al. 2022) provided support for this hypothesis, and this may also be reflected in other taxa.

On a more regional level, we increased the number of amphibian species recorded from the Cuito, Cuanavale, and Cuando rivers in Angola by Conradie et al. (2016) by nine species, and documented an additional 42 species associated with the Angolan Zambezi River basin. Ten of the species recorded here represent the southeasternmost records for Angola, some of which are also new records for the larger Okavango River basin (i.e., *Arthroleptis*

*stenodactylus*, *A. xenochirus*, *Breviceps ombelanonga*, *Hyperolius raymondi*, *Kassinula wittei*, *Ptychadena bunoderma*, *P. keilingi*, *Leptopelis* sp., and *Hyperolius* aff. *bocagei*).

In total, 125 nights, representing 240 total trapping nights, were spent surveying the region during both wet and dry seasons, without adding any additional species to the checklist. Thus, we now consider the upper catchments of the Cuito, Cuanavale, Cuando, and Lungwebungu rivers to be well surveyed for amphibians. However, the following species are expected to occur eastward to the Zambian border (compare to Broadley 1971; Pietersen et al. 2017; Bittencourt-Silva 2019), based the availability of appropriate habitat: *Breviceps adspersus*, *Breviceps poweri*, *Chiromantis xerampelina*, *Hildebrandtia ornata*, *Hemisus marmoratus*, *Phrynomantis bifasciatus*, *Phrynomantis affinis*, *Poyntonophrynus fenoulheti*, *Poyntonophrynus kavangensis*, *Ptychadena mapacha*, *Pyxicephalus adspersus*, and *Tomopterna cryptotis*.

The headwaters of the Okavango River basin, with peat lakes and extensive floodplains, harbor a high diversity of Hyperoliidae (three genera, comprising 12 species) and Ptychadenidae (nine species), compared to the more terrestrial families such as Bufonidae. Many of the species are regarded as local endemics to the headwaters (i.e., *Hyperolius raymondi*, *Hyperolius* aff. *bocagei*, *Kassina kuvangensis*, *Kassinula wittei*, and *Ptychadena keilingi*). The increased knowledge coupled with the presence of habitat specialist species will contribute to better conservation planning in these regions and the larger Okavango River basin.

**Acknowledgments.**—We thank the Wild Bird Trust, which administers the National Geographic Okavango Wilderness Project (2016–2019 National Geographic Society grant). Material was collected and exported under the following export permits issued by the Angolan Ministry of Environment Institute of Biodiversity (MINAMB): 31/GGPCC/2016, 89/INBAC. MINAMB/2017, 002/GGPTBOK/18, and 151/INBAC/MINAMB/2019. Ethical clearance for this study was obtained from the Port Elizabeth Museum (Bayworld) ethics committee (Ethical Clearance no. 2013 and 2017-2). We would also like to acknowledge the use of infrastructure and equipment provided by the NRF-SAIAB Aquatic Genomics Research Platform, and the funding channeled through the NRF-SAIAB Institutional Support System for generating barcodes. This project is endorsed and supported by the Governors of Cuando Cubango, Bié and Moxico provinces. Various colleagues are thanked for collecting herpetological material during their fieldwork, including Alexander Rebelo, Timóteo Júlio, Götz Neef, Roger Bills, Paul Skelton, Maans Booyens, and Kerllen Costa. WC thanks the Eastern Cape Province Department of Sport, Recreation, Arts, and Culture (DSRAC) and Port Elizabeth Museum (Bayworld) for granting special leave to take part in



these surveys. We thank Enviro-Insight for constructing and donating the drift fences required for the trapping exercise. NLB is currently supported by BIOPOLIS 2022-19.

## Literature Cited

- Altschul SF, Gish W, Miller W, Myers EW, Lipman DJ. 1990. Basic local alignment search tool. *Journal of Molecular Biology* 215: 403–410.
- Angel MF. 1924. Note préliminaire sur deux batraciens nouveaux, des genres *Rappia* et *Bufo*, provenant d'Afrique orientale anglaise (Mission Alluaud et Jeannel, 1911–1912). *Bulletin du Muséum National d'Histoire Naturelle. Paris* 30: 269–270.
- Baptista N, Conradie W, Vaz Pinto P, Branch WR. 2019. The amphibians of Angola: early studies and the current state of knowledge. Pp 243–281 In: *Biodiversity of Angola. Science and Conservation: a Modern Synthesis*. Editors, Huntley BJ, Ferrand N, Russo V, Lages F. Springer, Cham, Switzerland. 552 p.
- Baptista NL, Vaz Pinto P, Keates C, Edwards S, Rödel M-O, Conradie W. 2021. A new species of red toad, *Schismaderma* Smith, 1849 (Anura: Bufonidae), from central Angola. *Zootaxa* 5081(3): 301–332.
- Becker FS, Vaz Pinto P, Baptista N, Ernst R, Conradie W. 2023. The amphibians of the highlands and escarpments of Angola and Namibia. *Namibian Journal of Environment* (In Press).
- Benson DA, Cavanaugh M, Clark K, Karsch-Mizrachi I, Lipman DJ, Ostell J, Sayers EW. 2013. GenBank. *Nucleic Acids Research* 41(D1): D36–D42.
- Bittencourt-Silva GB. 2019. Herpetological survey of western Zambia. *Amphibian & Reptile Conservation* 13(2) [Special Section]: 1–28 (e181).
- Bittencourt-Silva GB, Bayliss J, Conradie W. 2020. First herpetological surveys of Mount Lico and Mount Socone, Mozambique. *Amphibian & Reptile Conservation* 14(2) [General Section]: 198–217 (e247).
- Bocage JVB. 1895. *Herpétologie d'Angola et du Congo*. Imprimerie Nationale, Lisbonne, France. 203 p.
- Branch WR, Schmitz A, Lobón-Rovira J, Baptista NL, António T, Conradie W. 2021. Rock island melody: a revision of the *Afroedura bogerti* Loveridge, 1944 group, with descriptions of four new endemic species from Angola. *Zoosystematics and Evolution* 97(1): 55–82.
- Branch WR, Baptista N, Vaz Pinto P, Conradie W. 2019a. The reptiles of Angola – history, updated checklists, endemism, hot spots, and future directions for research. Pp. 283–326 In: *Biodiversity of Angola. Science and Conservation: a Modern Synthesis*. Editors, Huntley BJ, Ferrand N, Russo V, Lages F. Springer, Cham, Switzerland. 552 p.
- Branch WR, Conradie W, Vaz Pinto P, Tolley KA. 2019b. Another Angolan Namib endemic species: a new *Nucras* Gray, 1838 (Squamata: Lacertidae) from south-western Angola. *Amphibian & Reptile Conservation* 13(2) [Special Section]: 82–95 (e199).
- Broadley DG. 1971. The reptiles and amphibians of Zambia. *The Puku: the Occasional Papers of the Department of Wildlife, Fisheries, and National Parks, Zambia* 6: 1–143.
- Brooks C. 2012. *Biodiversity Survey of the Upper Angolan Catchment of the Cubango-Okavango River Basin*. USAid-Southern Africa, Pretoria, South Africa. 151 p. Available: [http://the-eis.com/elibrary/sites/default/files/downloads/literature/Combined%20Angolan%20Biodiversity%20Survey%20Report\\_2012\\_08\\_05\\_14.pdf](http://the-eis.com/elibrary/sites/default/files/downloads/literature/Combined%20Angolan%20Biodiversity%20Survey%20Report_2012_08_05_14.pdf) [Accessed: 3 April 2023].
- Brooks C. 2013. *Trip Report: Aquatic Biodiversity Survey of the Lower Cuito and Cuando River Systems in Angola*. USAid-Southern Africa, Pretoria, South Africa. 43 p. Available: [http://the-eis.com/elibrary/sites/default/files/downloads/literature/Aquatic%20biodiversity%20survey%20of%20the%20lower%20Cuito%20and%20Cuando%20river%20systems%20in%20Angola\\_2013.pdf](http://the-eis.com/elibrary/sites/default/files/downloads/literature/Aquatic%20biodiversity%20survey%20of%20the%20lower%20Cuito%20and%20Cuando%20river%20systems%20in%20Angola_2013.pdf) [Accessed: 3 April 2023].
- Cei JM. 1977. Chaves para uma identificação preliminar dos batráquios anuros da R.P. de Angola. *Boletim da Sociedade Portuguesa de Ciências Naturais* 17: 5–26.
- Ceríaco LMP, Agarwal I, Marques MP, Bauer AM. 2020a. A review of the genus *Hemidactylus* Goldfuss, 1820 (Squamata: Gekkonidae) from Angola, with the description of two new species. *Zootaxa* 4746(1): 1–71.
- Ceríaco LMP, Heinicke MP, Parker KL, Marques MP, Bauer AM. 2020b. A review of the African Snake-eyed Skinks (Scincidae: *Panaspis*) from Angola, with the description of a new species. *Zootaxa* 4747(1): 77–112.
- Ceríaco LMP, Agarwal I, Marques MP, Bauer AM. 2020c. A correction to a recent review of the genus *Hemidactylus* Goldfuss, 1820 (Squamata: Gekkonidae) from Angola, with the description of two additional species. *Zootaxa* 4861(1): 92–106.
- Ceríaco LMP, Marques MP, Bandeira S, Agarwal I, Stanley EL, Bauer AM, Heinicke MP, Blackburn DC. 2018. A new earless species of *Poyntonophrynus* (Anura, Bufonidae) from the Serra da Neve Inselberg, Namibe Province, Angola. *ZooKeys* 780: 109–136.
- Ceríaco LMP, Marques MP, Bandeira SA. 2016. *Anfibios e Répteis do Parque Nacional da Cangandala*. Instituto Nacional da Biodiversidade e Áreas de Conservação and Museu Nacional de História Natural e da Ciência, Lisbon, Portugal. 96 p.
- Ceríaco LMP, Santos BS, Marques MP, Bauer AM, Tiutenko A. 2021. Citizen science meets specimens in old formalin filled jars: a new species of Banded Rubber Frog, genus *Phrynomantis* (Anura: Microhylidae) from Angola. *Alytes* 38(1–4): 18–48.

- Channing A. 2022. Color patterns to sequences: a perspective on the systematics of the *Hyperolius viridiflavus* group (Anura: Hyperoliidae) using mitochondrial DNA. *Zootaxa* 5134: 301–354.
- Channing A. 2001. *Amphibians of Central and Southern Africa*. Cornell University Press, Ithaca, New York, USA. 470 p.
- Channing A, Rödel MO, Channing J. 2012. *Tadpoles of Africa*. Edition Chimaira, Frankfurt am Main, Germany. 402 p.
- Channing A, Baptista N. 2013. *Amietia angolensis* and *A. fuscigula* (Anura: Pyxicephalidae) in southern Africa: a cold case reheated. *Zootaxa* 3640: 501–520.
- Channing A, Dehling JM, Lötters S, Ernst R. 2016. Species boundaries and taxonomy of the African river frogs (Amphibia: Pyxicephalidae: *Amietia*). *Zootaxa* 4155(1): 1–76.
- Channing A, Hillers A, Lötters S, Rödel MO, Schick S, Conradie W, Rödder R, Mercurio V, Wagner P, Dehling MJ, et al. 2013. Taxonomy of the super-cryptic *Hyperolius nasutus* group of Long Reed Frogs of Africa (Anura: Hyperoliidae), with descriptions of six new species. *Zootaxa* 3620(3): 301–350.
- Channing A, Rödel M-O. 2019. *Field Guide to the Frogs and Other Amphibians of Africa*. Struik Nature, Cape Town, South Africa. 408 p.
- Conradie W, Baptista NL, Verburgt L, Keates C, Harvey J, Júlio T, Neef G. 2021. Contributions to the herpetofauna of the Angolan Okavango-Cuando-Zambezi river drainages. Part 1: Serpentes (snakes). *Amphibian & Reptile Conservation* 15(2) [General Section]: 244–278 (e292).
- Conradie W, Branch WR, Measey GJ, Tolley KA. 2012a. Revised phylogeny of Sand Lizards (*Pedioplanis*) and the description of two new species from southwestern Angola. *African Journal of Herpetology* 60(2): 91–112.
- Conradie W, Branch WR, Measey JG, Tolley, KA. 2012b. A new species of *Hyperolius* Rapp, 1842 (Anura: Hyperoliidae) from the Serra da Chela mountains, southwestern Angola. *Zootaxa* 3269: 1–17.
- Conradie W, Deepak V, Keates C, Gower DJ. 2020a. Kissing cousins: a review of the African genus *Limnophis* Günther, 1865 (Colubridae: Natricinae), with the description of a new species from north-eastern Angola. *African Journal of Herpetology* 69(1): 79–107.
- Conradie W, Keates C, Lobón-Rovira J, Vaz Pinto P, Verburgt L, Baptista NL, Harvey J, Júlio T. 2020b. New insights into the taxonomic status, distribution, and natural history of De Witte's Clicking Frog (*Kassinula wittei* Laurent, 1940). *African Zoology* 55(4): 311–322.
- Conradie W, Keates C, Baptista NL, Lobón-Rovira J. 2022a. Taxonomical review of *Prosymna angolensis* Boulenger, 1915 (Elapoidea, Prosymnidae) with the description of two new species. *ZooKeys* 1121: 97–143.
- Conradie W, Schmitz A, Lobón-Rovira J, Becker FS, Vaz Pinto P, Hauptfleisch ML. 2022b. Rock island melody remastered: two new species in the *Afroedura bogerti* Loveridge, 1944 group from Angola and Namibia. *Zoosystematics and Evolution* 98(2): 435–453.
- Conradie W, Branch WR, Tolley KA. 2013. Fifty Shades of Grey: giving color to the poorly known Angolan Ash Reed Frog (Hyperoliidae: *Hyperolius cinereus*), with the description on a new species. *Zootaxa* 3635(3): 201–223.
- Conradie W, Keates C, Verburgt L, Baptista NL, Harvey J, Júlio T, Neef G. 2022c. Contributions to the herpetofauna of the Angolan Okavango-Cuando-Zambezi River drainages. Part 2: Lizards (Sauria), chelonians, and crocodiles. *Amphibian & Reptile Conservation* 16(2) [General Section]: 181–214 (e322).
- Conradie W, Bills R. 2017. Wannabe ranid: notes on the morphology and natural history of the Lemaire's Toad (Bufonidae: *Sclerophrys lemairii*). *Salamandra* 53(3): 439–444.
- Conradie W, Bill R, Branch WR. 2016. The herpetofauna of the Cubango, Cuito, and lower Cuando river catchments of south-eastern Angola. *Amphibian & Reptile Conservation* 10(2) [Special Section]: 6–36 (e126).
- Du Preez L, Carruthers V. 2017. *Frogs of Southern Africa: a Complete Guide*. Struik Publishers, Cape Town, South Africa. 520 p.
- Ernst R, Lautenschläger T, Branquima MF, Hölting M. 2020. At the edge of extinction: a first herpetological assessment of the proposed Serra do Pingano Rainforest National Park in Uíge Province, northern Angola. *Zoosystematics and Evolution* 96: 237–262.
- Ernst R, Nianguesso ABT, Lautenschläger T, Barej MF, Schmitz A, Hölting M. 2014. Relicts of a forested past: southernmost distribution of the Hairy Frog genus *Trichobatrachus* Boulenger, 1900 (Anura: Arthroleptidae) in the Serra do Pingano region of Angola with comments on its taxonomic status. *Zootaxa* 3779(2): 297–300.
- Ernst R, Schmitz A, Wagner P, Branquima MF, Hölting M. 2015. A window to Central African forest history: distribution of the *Xenopus fraseri* subgroup south of the Congo Basin, including a first country record of *Xenopus andrei* from Angola. *Salamandra* 52(1): 147–155.
- Frost R. 2023. Amphibian Species of the World: an Online Reference. Version 6.1, American Museum of Natural History, New York, USA. Available: <https://amphibiansoftheworld.amnh.org/index.php> [Accessed: 3 April 2023].
- Furman BL, Bewick AJ, Harrison TL, Greenbaum E, Gvoždík V, Kusamba C, Evans BJ. 2015. Pan-African phylogeography of a model organism, the African

- Clawed Frog *Xenopus laevis*. *Molecular Ecology* 24(4): 909–925.
- Hallermann J, Ceriaco LMP, Schmitz A, Ernst R, Conradie W, Verburgt L, Marques MP, Bauer AM. 2020. A review of the Angolan House Snakes, genus *Boaedon* Duméril, Bibron, and Duméril (1854) (Serpentes: Lamprophiidae), with description of three new species in the *Boaedon fuliginosus* (Boie, 1827) species complex. *African Journal of Herpetology* 69(1): 29–78.
- Hübner N. 2015. Diversity and phylogeography of Ridged Frogs (Anura: Ptychadena) in Northern Angola: morphological and molecular evidence. Master's thesis, University of Greifswald, Greifswald, Germany.
- Jongsma GFM, Barej MF, Barratt CD, Burger M, Conradie W, Ernst R, Greenbaum E, Hirschfeld M, Leaché AD, Penner J, et al. 2018. Diversity and biogeography of frogs in the genus *Amnirana* (Anura: Ranidae) across sub-Saharan Africa. *Molecular Phylogenetics and Evolution* 120: 274–285.
- Larson TR, Castro D, Behangana M, Greenbaum E. 2016. Evolutionary history of the river frog genus *Amietia* (Anura: Pyxicephalidae) reveals extensive diversification in Central African highlands. *Molecular Phylogenetics and Evolution* 99: 168–181.
- Laurent RF. 1972. Tentative revision of the genus *Hemisus*. *Annales du Musée Royal de l'Afrique Centrale. Série in Octavo, Science Zoologique, Tervuren* 194: 1–67.
- Laurent RF. 1964. Reptiles et amphibiens de l'Angola (troisième contribution). *Publicações Culturais da Companhia de Diamantes de Angola* 67: 11–165.
- Lobón-Rovira J, Conradie W, Baptista NL, Vaz Pinto P. 2022. A new species of Feather-tailed Leaf-toed Gecko, *Kolekanos* Heinicke, Daza, Greenbaum, Jackman, and Bauer, 2014 (Squamata, Gekkonidae) from the poorly explored savannah of western Angola. *ZooKeys* 1127: 91–116.
- Lobón-Rovira J, Conradie W, Buckley Iglesias D, Ernst R, Verisimmo L, Baptista N, Vaz Pinto P. 2021. Between sand, rocks, and branches: an integrative taxonomic revision of Angolan *Hemidactylus* Goldfuss, 1820, with description of four new species. *Vertebrate Zoology* 71: 465–501.
- Loveridge A. 1953. Zoological results of a fifth expedition to East Africa. IV. Amphibians from Nyasaland and Tete. *Bulletin of the Museum of Comparative Zoology* 110: 325–406.
- Marques MP, Parrinha D, Santo BS, Bandeira S, Butler BO, Sousa CAN, Bauer AM, Wagner P. 2022a. All in all it's just another branch in the tree: a new species of *Acanthocercus* Fitzinger, 1843 (Squamata: Agamidae), from Angola. *Zootaxa* 5099(2): 221–243.
- Marques MP, Ceriaco LMP, Heinicke MP, Chehouri RM, Conradie W, Tolley KA, Bauer A. 2022b. The Angolan Bushveld Lizards, genus *Heliobolus* Fitzinger, 1843 (Squamata: Lacertidae): integrative taxonomy and the description of two new species. *Vertebrate Zoology* 72: 745–769.
- Marques MP, Parrinha D, Ceriaco LMP, Brennan IG, Heinicke MP, Bauer AM. 2023. A new species of thick-toed gecko (*Pachydactylus*) from Serra da Neve and surrounding rocky areas of southwestern Angola. *Vertebrate Zoology* 73: 325–343.
- Marques MP, Ceriaco LMP, Bandeira S, Pauwels OSG, Bauer AM. 2019a. Description of a new Long-tailed Skink (Scincidae: *Trachylepis*) from Angola and the Democratic Republic of the Congo. *Zootaxa* 4568 (1): 51–68.
- Marques MP, Ceriaco LMP, Blackburn DC, Bauer AM. 2018. Diversity and distribution of the amphibians and terrestrial reptiles of Angola: atlas of historical and bibliographic records (1840–2017). *Proceedings of the California Academy of Sciences Series 4* 65(Supplement II): 1–501.
- Marques MP, Ceriaco LMP, Buehler MD, Bandeira SA, Janota JM, Bauer AM. 2020. A revision of the Dwarf Geckos, genus *Lygodactylus* (Squamata: Gekkonidae), from Angola, with the description of three new species. *Zootaxa* 4853(3): 301–352.
- Marques MP, Ceriaco LMP, Stanley EL, Bandeira SA, Agarwal I, Bauer AM. 2019b. A new species of Girdled Lizard (Squamata: Cordylidae) from the Serra da Neve Inselberg, Namibe Province, southwestern Angola. *Zootaxa* 4668(4): 503–524.
- Mertens R. 1938. Amphibien und Reptilien aus Angola gesammelt von W. Shack. *Senckenbergiana* 20(6): 425–443.
- Monard A. 1937. Contribution à la batrachologie d'Angola. *Bulletin de la Société Neuchâteloise des Sciences Naturelles* 62: 5–59.
- National Geographic Okavango Wilderness Project. 2017. *Initial Findings from Exploration of the Upper Catchments of the Cuito, Cuanavale, and Cuando Rivers, May 2015 to December 2016*. Wild Bird Trust, Johannesburg, South Africa. Available: [http://www.wildbirdtrust.com/wp-content/uploads/2018/03/NGOWP\\_report\\_1\\_FOR\\_PRINT\\_V14\\_English.pdf](http://www.wildbirdtrust.com/wp-content/uploads/2018/03/NGOWP_report_1_FOR_PRINT_V14_English.pdf) [Accessed: 3 April 2023].
- Nečas T, Kielgast J, Nagy ZT, Chifundera ZK, Gvoždík V. 2022. Systematic position of the Clicking Frog (*Kassinula* Laurent, 1940), the problem of chimeric sequences, and the revised classification of the family Hyperoliidae. *Molecular Phylogenetics and Evolution* 174: 1–11 (107514).
- Nielsen SV, Conradie W, Ceriaco LMP, Bauer AM, Heinicke MP, Stanley EL, Blackburn DC. 2020. A new species of Rain Frog (Brevicipitidae, *Breviceps*) endemic to Angola. *ZooKeys* 979: 133–160.
- Parrinha D, Marques MP, Heinicke MP, Khalid F, Parker KL, Tolley KA, Childers JL, Conradie W, Bauer AM, Ceriaco LMP. 2021. A revision of Angolan species in the genus *Pedioplanis* Fitzinger (Squamata: Lacertidae), with the description of a new species.



- Zootaxa* 5032(1): 1–46.
- Perret JL. 1977. Les *Hylarana* (Amphibiens, Ranidés) du Cameroun. *Revue Suisse de Zoologie* 84: 841–868.
- Perret JL. 1979. Remarques et mise au point sur quelques especes de *Ptychadena* (Amphibia, Ranidae). *Bulletin de la Société des Sciences Naturelles de Neuchâtel* 102: 5–21.
- Pickersgill M. 2007. *Frog Search. Results of Expeditions to Southern and Eastern Africa from 1993–1999*. Frankfurt Contributions to Natural History 28. Edition Chimaira, Frankfurt, Germany. 574 p.
- Pietersen DW, Pietersen EW, Conradie W. 2017. Preliminary herpetological survey of the Ngonye Falls and surrounding regions in south-western Zambia. *Amphibian & Reptile Conservation* 11(1) [Special Section]: 24–43 (e148).
- Poynton JC. 1964. The Amphibia of Southern Africa: a faunal study. *Annals of the Natal Museum* 17: 1–334.
- Poynton JC, Broadley DG. 1985a. Amphibia Zambesiaca 1. Scolecomorphidae, Pipidae, Microhylidae, Hemisidae, Arthroleptidae. *Annals of the Natal Museum* 26(2): 503–553.
- Poynton JC, Broadley DG. 1985b. Amphibia Zambesiaca 2. Ranidae. *Annals of the Natal Museum* 27(1): 115–181.
- Poynton JC, Broadley DG. 1987. Amphibia Zambesiaca 3. Rhacophoridae and Hyperoliidae. *Annals of the Natal Museum* 28(1): 161–229.
- Poynton JC, Broadley DG. 1988. Amphibia Zambesiaca 4. Bufonidae. *Annals of the Natal Museum* 29(2): 447–490.
- Poynton JC, Broadley DG. 1988. Amphibia Zambesiaca 5. Zoogeography. *Annals of the Natal Museum* 32(1): 221–277.
- Poynton JC, Loader SP, Conradie W, Rödel M-O, Liedtke C. 2016. Designation and description of a neotype of *Sclerophrys maculata* (Hallowell, 1854), and reinstatement of *S. pusilla* (Mertens, 1937) (Amphibia: Anura: Bufonidae). *Zootaxa* 4089: 73–94.
- Rödel M-O. 2000. *Herpetofauna of West Africa, Volume I: Amphibians of the West African Savanna*. Edition Chimaira, Frankfurt, Germany. 322 p.
- Ruas C. 1996. Contribuição para o conhecimento da fauna de batráquios de Angola Parte I: Famílias Pipidae, Bufonidae, Microhylidae, Ranidae, Hemisidae e Arthroleptidae. *Garcia de Orta. Series Zoology (Lisboa)* 21(1): 19–41.
- Ruas C. 2002. Batráquios de Angola em coleção no Centro de Zoologia. *Garcia de Orta. Series Zoology (Lisboa)* 24(1–2): 139–146.
- Schiøtz A. 1999. *Treefrogs of Africa*. Editions Chimaira, Frankfurt am Main, Germany. 350 p.
- Schmidt KP. 1936. The amphibians of the Pulitzer-Angola Expedition. *Annals of Carnegie Museum* 25: 127–133.
- Schmidt KP, Inger RF. 1959. Amphibians exclusive of the genera *Afraxalus* and *Hyperolius*. *Exploration du Parc National de l'Upemba. Mission G.F. de Witte, en collaboration avec W. Adam, A. Janssens, L. van Meel et R. Verheyen (1946–1949)* 56: 1–264.
- Smith A. 1849. *Illustrations of the Zoology of South Africa; Consisting Chiefly of Figures and Descriptions of the Objects of Natural History Collected during an Expedition into the Interior of South Africa, in the Years 1834, 1835, and 1836. Volume III. Reptilia, Part 28*. Smith, Elder, and Company, London, United Kingdom. 94 p.
- Stanley EL, Ceriaco LMP, Bandeira S, Valerio H, Bates MF, Branch WR. 2016. A review of *Cordylus machadoi* (Squamata: Cordylidae) in southwestern Angola, with the description of a new species from the Pro-Namib desert. *Zootaxa* 4061(3): 201–226.
- Telford N, Alexander GJ, Becker FS, Conradie W, Jordaan A, Kemp L, Le Grange A, Rebelo AR, Strauss S, Taft JM, et al. 2022. Extensions to the known geographic distributions of reptiles in the Karoo, South Africa. *Herpetological Conservation and Biology* 17(1): 145–154.
- Wagner P, Butler BO, Ceriaco LM, Bauer AM. 2021. A new species of the *Acanthocercus atricollis* (Smith, 1849) complex (Squamata, Agamidae). *Salamandra* 57: 449–463.
- Zimkus BM, Schick S. 2010. Light at the end of the tunnel: insights into the molecular systematics of East African Puddle Frogs (Anura: Phrynobatrachidae). *Systematics and Biodiversity* 8: 39–47.
- Zimkus BM, Rödel MO, Hillers A. 2010. Complex patterns of continental speciation: molecular phylogenetics and biogeography of sub-Saharan Puddle Frogs (*Phrynobatrachus*). *Molecular Phylogenetics and Evolution* 55(3): 883–900.



**Werner Conradie** has a Masters in Environmental Science (M.Env.Sc.) and 18 years of experience working with the southern African herpetofauna. His main research interests focus on the taxonomy, conservation, and ecology of amphibians and reptiles. Werner has published numerous principal and collaborative scientific papers, and has served on many conservation and scientific panels, including the Southern African Reptile and Amphibian Relisting Committees. He has undertaken research expeditions to many African countries, including Angola, Botswana, Lesotho, Malawi, Mozambique, Namibia, South Africa, Zambia, and Zimbabwe. Werner is currently the Curator of Herpetology at the Port Elizabeth Museum (Bayworld), South Africa.



**Chad Keates** is currently a Post-doctoral Fellow at the Port Elizabeth Museum, funded by research funds through Nelson Mandela University (Port Elizabeth, South Africa). Having recently completed his Ph.D. in Zoology, Chad's research focuses on the African herpetofauna and its evolutionary and ecological structuring. In Chad's short professional career, he has published several principal and collaborative peer-reviewed scientific papers and book chapters. As a strong advocate for reptile and amphibian awareness, Chad regularly conducts walks, talks, and presentations; and he has produced numerous popular scientific outputs on the subject. He has undertaken numerous expeditions in various African countries, such as Angola, Zambia, and South Africa, with a variety of both professional and scientific organizations.



**Luke Verburgt** is a consulting herpetologist in South Africa with over 19 years of herpetofauna survey experience across 23 African countries (Angola, Botswana, Cameroon, Democratic Republic of Congo, Ghana, Ivory Coast, Kenya, Lesotho, Liberia, Namibia, Madagascar, Malawi, Mali, Morocco, Mozambique, Republic of Guinea, São Tomé and Príncipe, Sierra Leone, South Africa, Swaziland, Tanzania, Uganda, and Zimbabwe). He is a co-owner of Enviro-Insight (Pretoria, South Africa), holds an M.Sc. in Zoology from the University of Pretoria, and is a registered scientific professional with the South African Council for Natural Scientific Professions (SACNASP). Luke has published more than 30 scientific articles, which include the descriptions of several new African herpetofauna species, and he is a co-author of the book *Snakes and other Reptiles of Zambia and Malawi* (Struik Random House Publishers, Cape Town, South Africa). He is also an extraordinary lecturer in the Department of Zoology & Entomology at the University of Pretoria.



**Ninda Baptista** is an Angolan biologist with an M.Sc. degree in Conservation Biology from the University of Lisbon (Portugal). She is currently pursuing a Ph.D. in Biodiversity, Genetics, and Evolution at the University of Porto (Portugal) that addresses the diversity of Angolan amphibians. Over the last 13 years, she has worked on research, *in-situ* conservation projects, and environmental consulting in Angola, including priority areas for conservation along the Angolan escarpment and highlands. She has conducted herpetological surveys throughout the country, and created a herpetological collection (Coleção Herpetológica do Lubango) that is currently deposited in Instituto Superior de Ciências da Educação da Huíla (ISCED – Huíla) in Angola. Ninda is an author of various scientific papers and book chapters on Angolan herpetology and ornithology. She also works on scientific outreach, producing magazine articles, books for children, and posters about the country's biodiversity in collaboration with Fundação Kissama (Luanda, Angola).



**James Harvey** lives in South Africa and works as an independent herpetologist, ecological researcher, and consultant. He holds degrees in Zoology, Hydrology, and Environmental Management, and has performed herpetological fieldwork widely, primarily within Africa, in such places as South Africa, Botswana, Zimbabwe, Angola, Malawi, Kenya, Mali, Democratic Republic of Congo, Madagascar, and Vietnam. His interests are diverse but center on the taxonomy, ecology, and conservation of herpetofauna and other biodiversity. James has contributed to conservation assessments, workshops, and Red Data publications for reptiles, amphibians, mammals, and plants for the southern and eastern African regions. James regularly attends herpetological conferences, has published several scientific papers, and has contributed to a number of herpetological publications as an author.



**Introductory Page.** *Lampropeltis herrerae* Van Denburgh and Slevin, 1923. The Islas Todos Santos Mountain Kingsnake “is endemic to the southern island of Isla Todos Santos, BC [Baja California]” (Grismer, 2002: 281). This individual was found on Isla Todos Santos Sur, Baja California, in the municipality of Ensenada. Isla Todos Santos Sur is one of a pair of islands lying just over 19 km off the coast of Ensenada in northern Baja California. Grismer (2002: 281) indicated that this snake “appears to be restricted to the rocky interior area of Isla Sur” and that it feeds on the lizards *Sceloporus occidentalis* and *Plestiodon skiltonianus*. Some authors have considered this kingsnake as a subspecies of *Lampropeltis zonata* (e.g., Heimes 2016), but our position on the validity of subspecies (see **Materials and Methods**) supports our recognition of this snake as a distinct species, a position that is also recognized by Grismer (2002) and on the *Mesoamerican Herpetology* website (<http://www.mesoamericanherpetology.com>; accessed 11 February 2023). Wilson et al. (2013a) calculated the EVS of this snake as 20, placing it in the highest vulnerability category. The IUCN does not recognize the taxonomy of this snake, and SEMARNAT considers it as Threatened (A). *Photo by Jorge H. Valdez-Villavicencio.*





# The herpetofauna of the Baja California Peninsula and its adjacent islands, Mexico: composition, distribution, and conservation status

<sup>1</sup>Anny Peralta-García, <sup>1</sup>Jorge H. Valdez-Villavicencio, <sup>2</sup>Lydia Allison Fucsko,  
<sup>3</sup>Bradford D. Hollingsworth, <sup>4</sup>Jerry D. Johnson, <sup>4</sup>Vicente Mata-Silva, <sup>4</sup>Arturo Rocha,  
<sup>5</sup>Dominic L. DeSantis, <sup>6</sup>Louis W. Porras, and <sup>7,8</sup>Larry David Wilson

<sup>1</sup>Conservación de Fauna del Noroeste, A.C., Ensenada, Baja California 22897, MÉXICO <sup>2</sup>Department of Humanities and Social Sciences, Swinburne University of Technology, Melbourne, Victoria, AUSTRALIA <sup>3</sup>Department of Herpetology, San Diego Natural History Museum, San Diego, California, 92101, USA <sup>4</sup>Department of Biological Sciences, The University of Texas at El Paso, El Paso, Texas 79968-0500, USA <sup>5</sup>Department of Biological & Environmental Sciences, Georgia College & State University, Milledgeville, Georgia 31061, USA <sup>6</sup>7705 Wyatt Earp Avenue, Eagle Mountain, Utah 84005, USA <sup>7</sup>Centro Zamorano de Biodiversidad, Escuela Agrícola Panamericana Zamorano, Departamento de Francisco Morazán, HONDURAS <sup>8</sup>1350 Pelican Court, Homestead, Florida 33035-1031, USA

**Abstract.**—The herpetofauna of the Baja California Peninsula, Mexico, consists of 172 species, including 18 anurans, three salamanders, 140 squamates, and 11 turtles. Among the 10 recognized geographic regions, the total number of herpetofaunal species ranges from a low of 27 in the Baja California Coniferous Forest Region to 84 in the Gulf Islands Region. The individual species occupy from one to 10 regions ( $\bar{x}$  = 3.3). The Gulf Islands Region is of the greatest significant conservation importance, inasmuch as it contains the largest overall number of species (84), the largest number of single-region species (39), and the greatest number of peninsular endemics (50). A similarity dendrogram based on the Unweighted Pair Group Method with Arithmetic Averages (UPGMA) indicates that the two most closely related regions are the Central Gulf Coast Region and the Arid Tropical Region, while the most distantly related region is the Baja California Coniferous Forest Region. Among the distributional categories, the greatest number of species are the non-endemics (81 of 172, or 47.1%), followed by the peninsular endemics (77, 44.8%), and finally, the non-natives (14, 8.1%). The principal environmental threats to the herpetofauna of the Baja California Peninsula are land conversion and habitat loss, water diversion and overuse, invasive species, livestock grazing, illegal trade, off-road activities, infectious diseases, and climate change. We assessed the conservation status of the native species by employing the SEMARNAT, IUCN, and EVS systems. Of the 158 native species, 85 are included in NOM-059-SEMARNAT, 15 are in the IUCN Threatened categories, and 76 have high EVS values. Two Relative Herpetofaunal Priority (RHP) methods were used to identify the rank order significance of the 10 geographic regions, and the highest ranks for both methods were obtained for the Gulf Islands Region. Thirty protected areas are located in the Baja California Peninsula, and they comprise almost one-half of the total area. All but eight of the 158 native herpetofaunal species are represented within the system of protected areas. Few herpetofaunal surveys of the protected areas have been completed thus far, so this is a major conservation goal for the future.

**Keywords:** Anurans, caudates, conservation status, physiographic regions, protected areas, protection recommendations, squamates, turtles

**Resumen.**—La herpetofauna de la Península de Baja California, México, consta de 172 especies, incluyendo 18 anuros, tres salamandras, 140 escamosos y 11 tortugas. Entre las 10 regiones geográficas reconocidas, el número total de especies de herpetofauna varía desde un mínimo de 27 en la Región del Bosque de Coníferas de Baja California hasta 84 en la Región de las Islas del Golfo. Las especies individuales ocupan de una a 10 regiones ( $\bar{x}$  = 3.3). La Región de las Islas del Golfo es de gran importancia para la conservación, ya que contiene el mayor número total de especies (84), el mayor número de especies de una sola región (39) y el mayor número de endémicas peninsulares (50). Un dendrograma de similitud basado en el método de grupos de pares no ponderados con promedios aritméticos (UPGMA) indica que las dos regiones más estrechamente relacionadas son la Región de la Costa Central del Golfo y la Región Tropical Árida. La región más lejanamente relacionada es la Región del Bosque de Coníferas de Baja California. Entre las categorías de distribución el mayor número de especies son las no endémicas (81 de 172 o 47.1%), seguidas de las endémicas peninsulares (77 o 44.8%) y, por último, las no nativas (14 o 8.1%). Las principales amenazas ambientales para la herpetofauna de la península de Baja California son la conversión de tierras y la pérdida de hábitat, el desvío y uso excesivo

**Correspondence.** anny.peralta@faunadelnoroeste.org (APG), j\_h\_valdez@yahoo.com.mx (JHV), lydiafucsko@gmail.com (LAF), bhollingsworth@sdnhm.org (BDH), jjohnson@utep.edu (JDJ), vmata@utep.edu (VMS), arocha3@miners.utep.edu (AR), dominic.desantis@gcsu.edu (DLD), empub@msn.com (LWP), bufodoc@aol.com (LDW)

de agua, las especies invasoras, el pastoreo de ganado, el comercio ilegal, las actividades todoterreno, las enfermedades infecciosas y el cambio climático. Evaluamos el estado de conservación de las especies nativas empleando los sistemas de SEMARNAT, UICN y EVS. De las 158 especies nativas, 85 están incluidas en la NOM-059-SEMARNAT, 15 en las categorías Amenazadas de la UICN y 76 presentaron valores elevados de EVS. Mediante el uso de los dos métodos de prioridad herpetofaunística relativa (RHP) para identificar la importancia del orden de rango de las 10 regiones geográficas, se obtuvieron los dos rangos más altos para la región de las Islas del Golfo. Treinta áreas protegidas se encuentran en la Península de Baja California y comprenden casi la mitad del área total. Todas menos ocho de las 158 especies nativas de herpetofauna están representadas dentro del sistema de áreas protegidas. Se han completado pocos estudios de herpetofauna para las áreas protegidas, por lo que este es un objetivo de conservación importante para el futuro.

**Palabras Claves:** Anuros, caudados, escamosos, tortugas, regiones fisiográficas, áreas protegidas, estatus de conservación, recomendaciones de protección

**Citation:** Peralta-García A, Valdez-Villavicencio JH, Fucsko LA, Hollingsworth BD, Johnson JD, Mata-Silva V, Rocha A, DeSantis DL, Porras LW, and Wilson LD. 2023. The herpetofauna of the Baja California Peninsula and its adjacent islands, Mexico: composition, distribution, and conservation status. *Amphibian & Reptile Conservation* 17(1&2): 57–142 (e326).

**Copyright:** © 2023 Peralta-García et al. This is an open access article distributed under the terms of the Creative Commons Attribution License [Attribution 4.0 International (CC BY 4.0): <https://creativecommons.org/licenses/by/4.0/>], which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited. The official and authorized publication credit sources, which will be duly enforced, are as follows: official journal title *Amphibian & Reptile Conservation*; official journal website: [amphibian-reptile-conservation.org](http://amphibian-reptile-conservation.org).

**Accepted:** 2 August 2023; **Published:** 19 November 2023

*“...Baja California possesses a wild, intangible allure. An innate sense of adventure, heightened by a hint of danger and the unknown, beckons many explorers off the highway into Baja’s harsh, poorly understood interior. Baja California’s jagged, snow-covered peaks, volcanic badlands, parched deserts with relentless summer temperatures, and arid, uninhabited desert islands have been reluctant to give up their secrets. There is still much knowledge to be attained and many personal challenges to be met.”*

L. Lee Grismer (2002)

## Introduction

One of the most distinctive features of the physiography of Mexico is the Baja California Peninsula, a finger-like extension of land flanked by small islands, which comprises two states of the 32 federal entities in the country, i.e., Baja California to the north and Baja California Sur to the south. These two states are separated from one another at latitude 28° N, just slightly to the north of Punta Eugenia, the northwestern point of the Península de Vizcaíno (Grismer 2002).

A succinct description of the physiography of the peninsula is provided in the now-classic volume on the herpetofauna authored by L. Lee Grismer (2002), in which the introduction (pg. 3) includes the following quote: “Today Baja California is a thin northwest to southeast-tending peninsula nearly 1,300 km long. It is situated between 32° 30’ N latitude and 117° W longitude at its northwestern corner and [between] 23° N and 110° W at its southern tip. Its width ranges from approximately 240 km along the U.S.–Mexico border to less than 30 km at the Isthmus of La Paz. It is separated from the state of Sonora by the Río Colorado in the north and from the rest of Sonora and mainland Mexico by the Gulf of

California, approximately 160 km wide. The area of Baja California is approximately 143,400 km<sup>2</sup>, and its coastline is approximately 3,300 km long. Associated with the coastline are forty-five major islands, each at least 1.3 km<sup>2</sup> in area. Several smaller islands are also associated with Baja California, and an additional 10 or so major islands are principally associated with the Mexican states of Sonora and Sinaloa... [which are not considered in this paper].” More details on the physiography of this peninsula are provided in the section below entitled “Physiography and Climate.”

With an area of 71,450 km<sup>2</sup>, the state of Baja California is the 12<sup>th</sup> largest in Mexico and the 19<sup>th</sup> most densely populated. The corresponding data for the state of Baja California Sur are 73,909 km<sup>2</sup>, the 9<sup>th</sup> largest, and the 32<sup>nd</sup> most densely populated (<http://inegi.org.mx>; accessed 8 June 2023).

Given the relative geographic isolation of the peninsula from the mainland of both the United States and Mexico, this area is expected to be characterized by a significant degree of endemism, especially since the mainland of the peninsula is flanked by a large number of variously sized islands. Also, given the limited range of these endemic species, they are expected to be subjected to the usual range of anthropogenic threats. Thus, the purpose of this paper is to examine these aspects as they relate to the interesting herpetofauna of this offset region of Mexico.

## Materials and Methods

### Our Taxonomic Position

In this paper, we follow the same taxonomic position as explained in previous works on other portions of Mesoamerica (Johnson et al. 2015; Mata-Silva et al. 2015; Terán-Juárez et al. 2016; Woolrich-Piña et al.

2016; Nevárez-de los Reyes et al. 2016; Cruz-Sáenz et al. 2017; Gonzalez-Sánchez et al. 2017; Woolrich-Piña et al. 2017; Lazcano et al. 2019; Ramírez-Bautista et al. 2020; Torres-Hernández et al. 2021; Cruz Elizalde et al. 2022). Johnson et al. (2015) can be consulted for a detailed statement of this position, with special reference to the subspecies concept.

### System for Determining Distributional Status

The system developed by Alvarado-Díaz et al. (2013) for the herpetofauna of Michoacán was employed to ascertain the distributional status of members of the herpetofauna of the Baja California Peninsula, which consists of the following four categories: SE, endemic to the Baja California Peninsula; CE, endemic to Mexico; NE, not endemic to Mexico; and NN, non-native in Mexico.

### Systems for Determining Conservation Status

The following three systems were used to determine the conservation status of the 158 native species of amphibians and reptiles in the Baja California Peninsula: SEMARNAT, IUCN, and EVS. The SEMARNAT system, established by the Secretaría de Medio Ambiente y Recursos Naturales, lists only the threatened species in the NOM 059-SEMARNAT-2010 (SEMARNAT 2010, 2019) under three categories: Endangered (P), Threatened (A), and Subject to Special Protection (Pr). For species not included on that list, we used the designation “No Status;” however, we acknowledge that the SEMARNAT list is not meant to include non-threatened species. For species included on that list for which taxonomy has changed, we maintain the conservation status of the previous taxonomic entity, following section six of NOM-059-SEMARNAT-2010 (SEMARNAT 2010).

The IUCN system (<https://www.iucnredlist.org>) is utilized widely for assessing the conservation status of species on a global scale. The categories include Extinct (EX), Extinct in the Wild (EW), Critically Endangered (CR), Endangered (EN), Vulnerable (VU), Near Threatened (NT), Least Concern (LC), Data Deficient (DD), and Not Evaluated (NE). Collectively, the three categories of Critically Endangered, Endangered, and Vulnerable are termed the “threat categories” to distinguish them from the other six.

The EVS system was applied here for the 158 native species, following Wilson et al. (2013a,b). A re-evaluation was conducted because of taxonomic changes that have transpired since their original EVS values were reported, as well as regional differences in the degree of human persecution in mainland Mexico, as required for criterion C. The EVS measure was not designed for use with marine species (e.g., marine turtles and sea snakes), and is generally not applied to non-native species.

### The Mexican Conservation Series

The Mexican Conservation Series (MCS) was initiated in 2013, with a study of the herpetofauna of Michoacán (Alvarado-Díaz et al. 2013) that was published as part of a set of five papers designated as the Special Mexico Issue in *Amphibian & Reptile Conservation*. The basic format of the entries in the MCS was established in that paper, i.e., examining the composition, physiographic distribution, and conservation status of the herpetofauna of a given Mexican state or group of states. Two years later, the MCS resumed with a paper on the herpetofauna of Oaxaca (Mata-Silva et al. 2015). That year, Johnson et al. (2015) authored a paper on the herpetofauna of Chiapas, and three entries in the MCS appeared the next year, covering Tamaulipas (Terán-Juárez et al. 2016), Nayarit (Woolrich-Piña et al. 2016), and Nuevo León (Nevárez-de los Reyes et al. 2016). The following year three additional entries appeared, covering Jalisco (Cruz-Sáenz et al. 2017), the Mexican Yucatan Peninsula (González-Sánchez et al. 2017), and Puebla (Woolrich-Piña et al. 2017). Subsequently, similar articles on Coahuila (Lazcano et al. 2019), Hidalgo (Ramírez-Bautista et al. 2020), and Veracruz (Torres-Hernández et al. 2021) were published. Last year, articles on Querétaro (Cruz Elizalde et al. 2022), Tabasco (Barragán-Vázquez et al. 2022), and Guanajuato (Leyte-Manrique et al. 2022) appeared. Thus, this article on the herpetofauna of the Baja California Peninsula is the 16<sup>th</sup> entry in this series.

### Geography and Climate

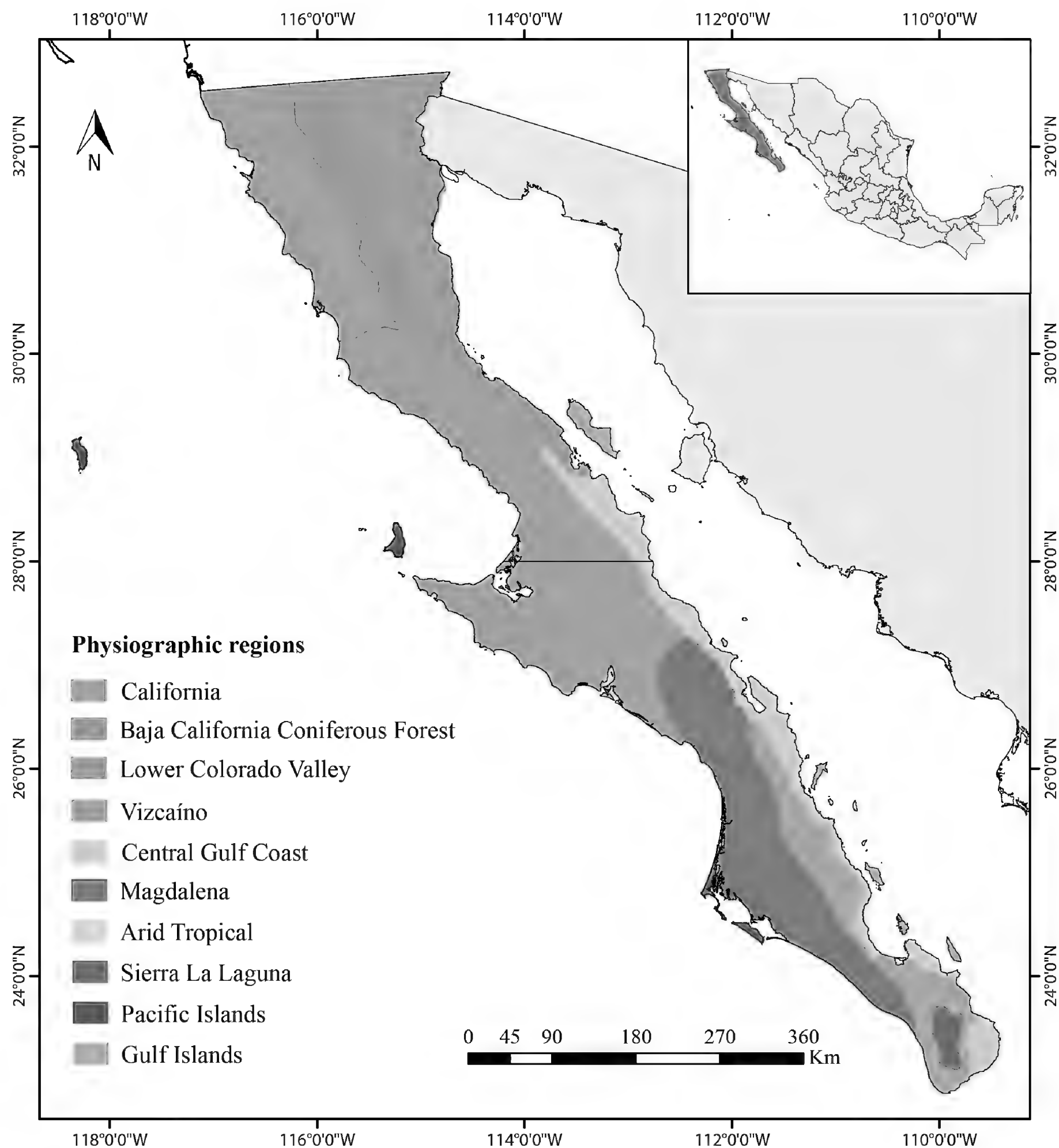
#### Geographic Regions

The formation of the Baja California Peninsula in northwestern Mexico originated from a complex interaction of plate tectonics, which resulted in the formation of the Gulf of California. There are a large number of climatic variables and a varied topography along the peninsula (Shreve and Wiggins 1964; Grismer 2002; Hollingsworth et al. 2015). The interactions among these climatic and topographic variables have given rise to several distinct physiographic regions.

These characteristics also resulted in the formation of different phytogeographical regions, which can be distinguished by the different types of vegetation (Fig. 1). This situation is linked to the “double ecological polarity” that occurs on the peninsula (González-Abraham et al. 2010). First, a north-to-south gradient with a temperate climate in the northwest and a tropical climate in the south contains an extensive arid transition region between the two. Then, an east-to-west gradient has resulted from the combination of a mountain range distributed intermittently along the peninsula and the influence of two different marine water masses which are cold in the Pacific and warm in the Gulf of California (González-Abraham et al. 2010).



The herpetofauna of the Baja California Peninsula



**Fig. 1.** Geographic regions of the Baja California Peninsula, Mexico.

The distribution of the herpetofauna of the Baja California Peninsula coincides with the phytogeographic regions (Grismer 1994, 2002). As indicators of the natural biotic provinces, they likely are influenced by the same environmental characteristics that limit the distributions of amphibians and reptiles (Grismer 2002). The following 10 regions have been identified: (1) California; (2) Coniferous Forest; (3) Lower Colorado Desert; (4) Vizcaíno Desert; (5) Central Gulf Coast Desert; (6) Magdalena; (7) Sierra La Laguna; (8) Arid Tropical; (9) Pacific Islands; and (10) Gulf Islands. Shreve and Wiggins (1964), Wiggins (1980), and Grismer (2002) defined these regions, and they are briefly described below.

*California Region.* Located in the northwestern quarter of the peninsula, this region (Fig. 2) extends 275 km from the border with the United States to the vicinity of El Rosario along the Pacific coast, where it slowly intergrades into the Vizcaíno Desert Region to the south (Hollingsworth et al. 2015). During the Pleistocene, the California Region likely extended farther southward onto the peninsula. However, successive periods of aridification replaced these communities with deserts that include remnants of the California Region flora (Van Devender 1990). Today, the California Region is confined to the northern state of Baja California. To the east, the region extends up the Sierra Juárez and Sierra San Pedro Mártir to an elevation of 2,000 m at the start



**Fig. 2.** California Region, as seen along the road to Sierra San Pedro Mártir, Baja California. *Photo by Jorge H. Valdez-Villavicencio.*



**Fig. 3.** Coniferous forest in Sierra San Pedro Mártir, Baja California. Picacho del Diablo (left), the highest peak on the peninsula (3,100 m), is seen in the background. *Photo by Felipe León.*

of the pine belt, with a mixed chaparral-coniferous forest zone found at elevations between 1,500 and 2,000 m (Delgadillo 2004). Farther to the east, the California Region comes into contact and intermixes with the Lower Colorado Desert in low-elevation passes between the mountains. Throughout this region, oak and willow forests primarily border the rivers that flow down from the mountains to the west, and thus dominate the riparian zones, and many of these rivers still flow year-round at mid to high elevations. Overall, the region is relatively cool for most of the year, due to the cold California Current that drives winds blowing off the Pacific Ocean waters, bathing the low elevations in morning fog (Hastings and Turner 1965; Markham 1972; Meigs

1966). Temperatures during the summer months average 20 to 25 °C, whereas winter temperatures average 10.0 to 12.5 °C. The precipitation comes from the tail end of Pacific winter storms that originate from the north, with a prominent decline in rain farther south (Humphrey 1974). This region is a southern extension of the coastal sage scrub and chaparral communities of southern California, which are dominated by sages (*Artemisia* and *Salvia*), buckwheat (*Eriogonum*), lilacs (*Ceanothus*), and chamise (*Adenostoma*).

*Coniferous Forest Region.* Prominent forests occur in both the Sierras Juárez and San Pedro Mártir (Fig. 3), which extend from the United States in the north and represent the southernmost segment of the Sierran



**Fig. 4.** Vegetation in the Lower Colorado Region at Valle del Borrego, Sierra San Felipe, Baja California. *Photo by Jorge H. Valdez-Villavicencio.*

Montane Conifer Forest (Pase 1982). These Peninsular Range mountains are confined to the northern state of Baja California and extend southward from the United States-Mexico border for approximately 300 km. Oriented in a north-south direction, they gradually rise along their western slopes, crest with peaks as high as 3,100 m, and rapidly descend to the desert floor with steep eastern escarpments. The mean monthly air temperatures range from -0.2 to 17 °C. This region has the most reliable precipitation on the peninsula, and receives more rainfall than any other area in Baja California (Hastings and Turner 1965). The majority of the precipitation falls during winter and spring in the form of snow at the higher elevations. Summer brings more variable thunderstorms, when the tropical air moving in a northwesterly direction is uplifted and cooled along the steep eastern slopes of the mountains (Humphrey 1974). The mountains contain extensive meadows that fill with water. The floristic composition of the region is relatively diverse, defined mainly by large shrubs and trees, which are dominated by Jeffrey Pines (*Pinus jeffreyi*), manzanitas (*Arctostaphylos*), oaks (*Quercus*), firs (*Abies*), aspens (*Populus*), and cedars (*Calocedrus*) (Garcillán et al. 2012).

**Lower Colorado Desert Region.** The Lower Colorado Desert (Fig. 4) is the largest subregion of the Sonoran Desert and extends across southeastern California, southwestern Arizona, northwestern Sonora, and

northeastern Baja California (Shreve 1951). On the peninsula, this low-elevation desert extends from the Peninsular Ranges to the west and the Colorado River to the east. Confined to the northern state of Baja California, it extends for 450 km southward from the border of the United States to the vicinity of Bahía de los Ángeles, where it intergrades widely with the Gulf Coast Desert Region (Peinado et al. 1994). This region contains the late Miocene to Pliocene sedimentary deposits of the Colorado River and the receding waters of the Gulf of California, and is composed of broad expansive basins with elevations ranging from below sea level to 400 m (Spencer and Pearthree 2001). Along this region's northeastern boundary, the Río Colorado once provided a rich aquatic ecosystem in the middle of a harsh desert. Today, water no longer flows from the river to the Gulf of California due to its diversion for agricultural and urban use. The mean temperatures for July and August are above 32.5 °C, while the mean winter temperature is 12.5 °C (Markham 1972). Lying in the rainshadow of the Sierras Juárez and San Pedro Mártir, this region is the hottest and most barren desert on the peninsula, as it receives less than 5 cm of annual rainfall. Creosote Bush (*Larrea tridentata*), Burro Weed (*Ambrosia dumosa*), and Ocotillos (*Fouqueria splendens*) dominate the vegetation of this region, but it also contains other arid-adapted plants such as mesquites, agaves, palo verde, and various forms of cacti (González-Abraham et al. 2010).





**Fig. 5.** A view of the Vizcaíno Region at Sierra La Asamblea, Baja California, as seen from Transpeninsular Highway 1. *Photo by Jorge H. Valdez-Villavicencio.*



**Fig. 6.** South of Vizcaíno, Baja California Sur; fog is an essential component of this region. *Photo by Jorge H. Valdez-Villavicencio.*

*Vizcaíno Desert Region.* This region (Figs. 5–6) is located in the central portion of the peninsula, and extends from the California and Lower Colorado Desert Regions to Laguna San Ignacio. It is bordered by the Pacific Ocean to the west, but its eastern extent varies greatly and generally is limited by the Central Gulf Coast Desert Region that borders the Gulf of California. The southern portion of the Vizcaíno Desert Region is much flatter, with elevations just above sea level, whereas the northern portion consists of smaller

mountain ranges, mesas, and dry washes that are no higher than 1,000 m (Bostic 1971). This region spans both Baja California and Baja California Sur. Many spring-fed oases are found throughout this region and support more mesic communities (Grismer and McGuire 1993). It also experiences a “fog type” temperate desert climate, with limited winter and summer precipitation (Meigs 1966). The mild climate is greatly influenced by prevailing westerly winds coming off the Pacific Ocean, which generate the conditions for heavy fog (Bostic



**Fig. 7.** Vegetation in the Central Gulf Coast Region, near San Basilio, Baja California Sur. *Photo by Alan Harper.*



**Fig. 8.** Vegetation in the Central Gulf Coast Region near Bahía Concepción, Baja California Sur. *Photo by Jorge H. Valdez-Villavicencio.*

1971). Rainfall occurs in the winter and averages only 5.5 cm. The mean air temperatures range between 23 and 28 °C during the summer, and 15° and 18 °C in winter (Markham 1972). Overall, this region often has overcast skies and a mild climate that receives little rain. In much of the region, the vegetation is open, stunted, widely spaced, and depauperate, because of continuous onshore winds from the Pacific Ocean (Grismer 2002). In areas protected from the winds, plant diversity increases sharply and the dominant plants include Cirios (*Fouquieria columnaris*), Baja California Tree Yucca (*Yucca valida*), Cardón (*Pachycereus pringlei*), Elephant Trees (*Pachycormus discolor*), mesquites (*Prosopis*), and agaves (*Agave*) (Garcillán et al. 2012).

*Central Gulf Coast Desert Region.* This long and narrow region (Figs. 7–9) lies along the eastern coast

of the peninsula, extends southward from Bahía de los Ángeles to the Cape Region, and spans both states on the peninsula (Shreve and Wiggins 1964). Broad intermixing occurs between this region and the Lower Colorado Desert to the north (Peinado et al. 1994), whereas its boundaries to the west are marked by the uplift of the Peninsular Ranges. The elevation ranges from sea level to 800 m. This region is hot and arid, and receives nearly all of its precipitation during the summer and fall. Severe droughts occur in spring, a time when the mean precipitation is only 0.20 cm (Hastings and Turner 1965; Humphrey 1974). The majority of the Central Gulf Coast Desert rainfall originates from southern convectional storms, and appears as run-off from the bordering Peninsular Range. Occasionally, the region receives rainfall from hurricanes that originate





**Fig. 9.** Vegetation in the Central Gulf Coast Region, near San Basilio, Baja California Sur. *Photo by Jorge H. Valdez-Villavicencio.*



**Fig. 10.** View of the Magdalena Region at La Purisima, Baja California Sur. *Photo by Gerardo Marrón.*

in the southern tropical waters and track northward. Despite periods of severe drought, the annual mean rainfall can reach 16.8 cm (Hastings and Turner 1965) when there has been an active hurricane season. The mean temperatures for the warmest summer months are above 30 °C, whereas the mean winter temperatures fall to around 15 °C (Markham 1972). Arid-adapted plants that include Elephant Trees (*P. discolor*), Palo Blanco (*Lysiloma candidum*), lomboy (*Jatropha*), Palo Adan (*Fouquieria diguettii*), and various forms of cacti, including large columnar forms, characterize the vegetation. Some mangroves are also present in the southern part of this region, where Black Mangrove (*Avicennia germinans*) and White Mangrove (*Laguncularia racemosa*) are the most predominant species (González-Zamorano et al. 2011; Garcillán et al. 2012).

**Magdalena Region.** This region (Figs. 10–12) extends from Laguna San Ignacio to the Cape Region, along the southwestern coast of the peninsula, and receives the Pacific drainages of the Sierra Guadalupe and Sierra La Giganta. Its eastern border is defined by the uplift of the Peninsular Ranges and its contact with the Central Gulf Coast Desert. This region is confined to Baja California Sur, and is composed of a rugged mountainous region along the eastern border and a flat open plain along the western portion. The mountains contain volcanic badlands interspersed with spring-fed oases (Grismer and McGuire 1993), whereas the western plains consist of sandy fluvial deposits that rely on run-off from the mountains. The elevation in this region ranges from sea level to 1,100 m. The coastal areas receive cool morning fog, but precipitation is low and unpredictable. The mean annual rainfall can reach 12.5 cm (Hastings and Turner





**Fig. 11.** View of the Magdalena Region at Los Burros, Baja California Sur. *Photo by Bradford Hollingsworth.*



**Fig. 12.** View of the Magdalena Region at 3.4 km NW Puerto Cancún, Baja California Sur. *Photo by Gerardo Marrón.*

1965). The mean temperatures for the warmest summer months are above 29 °C, whereas the mean winter temperatures are only 17 °C (Markham 1972). Creosote Bush (*Larrea tridentata*), Elephant Trees (*Bursera*), Peninsular Palo Verde (*Parkinsonia florida*), and columnar and various other types of cacti, mesquites, and palms (*Washingtonia*) in oases dominate the vegetation (Garcillán et al. 2012).

**Sierra La Laguna Region.** The Sierra La Laguna Region (Fig. 13) is located at the southern tip of the Baja California Peninsula, within the Cape Region, and contains dense forests at the higher elevations. Formed by granitic and intrusive rock, these mountains rise to an

elevation of 2,200 m, and have undergone a long history of isolation (Garcillán et al. 2012). Confined to the state of Baja California Sur, this region extends from above 800 m and receives its moisture from summer convective storms and passing hurricanes. The mean annual rainfall can reach 29.6 cm (Hastings and Turner 1965). Due to a wide range in elevation, the temperatures vary greatly. At the higher elevations, the mean temperatures for the warmest summer months are above 18 °C, whereas the mean winter temperatures are only 8 °C (Markham 1972). The vegetation contains numerous endemics, and the mid-elevation slopes are covered with oak woodlands (*Quercus tuberculata*; *Q. brandegeei*), while the upper



**Fig. 13.** A view of Sierra La Laguna, the highest mountain range in Baja California Sur, as seen from Segundo Valle. *Photo by Jorge H. Valdez-Villavicencio.*



**Fig. 14.** Arid Tropical Region vegetation is evident along Transpeninsular Highway 1, south of La Paz between San Antonio and San Bartolo, Baja California Sur. *Photo by Jorge H. Valdez-Villavicencio.*

elevations are covered with pine-oak woodlands (*Q. devia* and *Pinus lagunae*), Peninsular Madrone (*Arbutus peninsularis*), and Belding Bear-grass (*Nolina beldingii*) (Garcillán et al. 2012).

**Arid Tropical Region.** This region (Fig. 14) is comprised of the Sierra La Giganta, located along the central uplift of the southern peninsula and the lowlands of the Cape Region, and extends from south of the Isthmus of La Paz to the southern terminus of the peninsula. In the Cape Region, two well-differentiated landscapes of mountain foothills and coastal alluvial plains characterize this region (Garcillán et al. 2012). The foothills extend from 500 to 1,000 m in elevation and intermix with the Sierra La Laguna Region, whereas the alluvial plains are

found from sea level to 500 m. This region is confined to the state of Baja California Sur. The mean annual rainfall can reach 29.2 cm (Hastings and Turner 1965), and usually occurs in late summer and early fall. This region is hot, with mean temperatures for the warmest summer months above 28.8 °C (Markham 1972). The vegetation is composed of tropical dry forests in the foothills that remain leafless in the dry season, but rebound with the late summer rains. The vegetation includes a variety of woody trees like Palo Blanco (*Lysiloma candidum*), Mauto (*L. divaricatum*), Plumeria (*Plumeria rubra*), and Cardón Barbón (*Pachycereus pecten-aboriginum*). The coastal lowlands are composed of a fleshy-stemmed shrubland that includes elephant trees (*Bursera*), Ashy





**Fig. 15.** A view from the southern end of the Todos Santos Sur island in which the northern part of the south island and the Todos Santos Norte island, including its lighthouse, are visible. *Photo by Jorge H. Valdez-Villavicencio.*



**Fig. 16.** Islas los Coronado (four islands), Baja California. View from Coronado Sur, of Coronado Norte, Pilon de Azúcar, and Coronado Medio. *Photo by Jorge H. Valdez-Villavicencio.*

Limberbush (*Jatropha cinerea*), figs (*Ficus brandegeei*), and succulents (Garcillán et al. 2012).

*The Pacific Islands.* Along the west coast of the peninsula, the Pacific Ocean is dominated by the California Current System, which extends from Alaska to northern Baja California, but seasonally extends southward to the tip of the peninsula (Hickey 1979; Badan-Dangon et al. 1989). The California Current consists of a year-round equatorward surface flow that brings cool water down the coastal waters of the peninsula (Kurczyn et al. 2019). On the contrary, the coast of mainland Mexico to the south is exposed to warmer waters from the Equatorial

Countercurrent that feeds the Costa Rica Coastal Current flowing poleward, bringing warm counterflows northward along the peninsula (Badan-Dangon et al. 1989). During El Niño years, the poleward surface currents intensify and bring warmer water farther north, along with some marine reptiles (Grismer 2002). The west coast of the peninsula also contains extensive lagoons and bays which provide important warm-water shelters that are preferred by some sea turtles (Senko et al. 2010).

The Pacific Islands (Figs. 15–17) extend along much of the length of the peninsula, from the Islas Coronado offshore from Tijuana, which are located just south of the





**Fig. 17.** Todos Santos Sur Island is almost entirely invaded by different species of dense grasses (e.g., *Bromus* and *Avena*) and ice plants, which displace the native vegetation. The invasion of introduced grasses and ice plants (*Mesembryanthemum crystallinum*) occurs throughout the peninsula. Photo by Jorge H. Valdez-Villavicencio.

border between California in the United States and Baja California in Mexico, to Isla Creciente, the southernmost island of the insular group, which lies off the Magdalena region of the southwestern peninsula. As noted by Grismer (2002: 9), “the islands of the Pacific coast of Baja California are all landbridge in origin, except for the Islas San Benito, which are oceanic...The largest and most environmentally diverse Pacific island is Isla Cedros, which reaches nearly 1,200 m in elevation. The remaining islands are generally low, small, and rocky, with the notable exception of Isla Creciente, the long, narrow sandbar enclosing the southern end of Bahía Magdalena.”

*The Gulf Islands.* The Gulf of California is a 1,400 km long semi-enclosed sea that extends from a depth of more than 3,000 m at the southern entrance to only

200 m at its enclosed end at the Colorado River outlet (Álvarez-Borrego 2002; Lavin and Marinone 2003). The entrance to the Gulf of California is exposed to warmer waters from the poleward flowing Costa Rica Coastal Current (Badan-Dangon et al. 1989). The current in the sea flows northward along the mainland coast and southward down the peninsula during the summer months, and then reverses direction during the winter (Álvarez-Borrego 2002). The mean temperatures in the northern portion of the sea are 8.2 °C in December and 32.6 °C in August (Álvarez-Borrego 2002). Numerous islands and bays (Figs. 18–23) provide a diversity of coastal microhabitats that are favorable to marine reptiles, including sandy beaches, mangrove forests, reefs, and shelters, whereas deep water pelagic conditions exist in the southern Gulf of California,



**Fig. 18.** View of the shore of Isla Carmen located in the southern Gulf of California and protected within Parque Nacional Bahía de Loreto. This island is part of the Bahía de Loreto National Park. *Photo by Bradford D. Hollingsworth.*



**Fig. 19.** View of Puerto Balandra, Isla Carmen, a small bay on the northwestern side of the island, representing the typical arid habitat found within the Gulf Island Region, and home to the single-region endemics *Sauromalus slevini* and *Aspidoscelis carmenensis*. *Photo by Bradford D. Hollingsworth.*

which support open-water species (Santamaría-del-Angel et al. 1994; Lavin and Marinone 2003).

### Climate

*Temperature.* The monthly minimum, mean, and maximum temperatures for one representative locality from each of the 10 geographic regions we recognize

in the Baja California Peninsula are given in Table 1. The elevations for these localities range from 3 m at Isla Cedros in the Pacific Islands to 1,580 m at Laguna Hanson in the Baja California Coniferous Forest.

The mean annual temperature (MAT) is highest at Loreto (elevation 20 m) in the Central Gulf Coast Region and lowest at Laguna Hanson (elevation 1,580 m) in the Baja California Coniferous Forest Region.





**Fig. 20.** View of the uninhabited Isla San Francisco, a small island located in the southern Gulf of California and home to the single-region endemics *Aspidoscelis celeripes* and *A. franciscensis*. Photo by Bradford D. Hollingsworth.

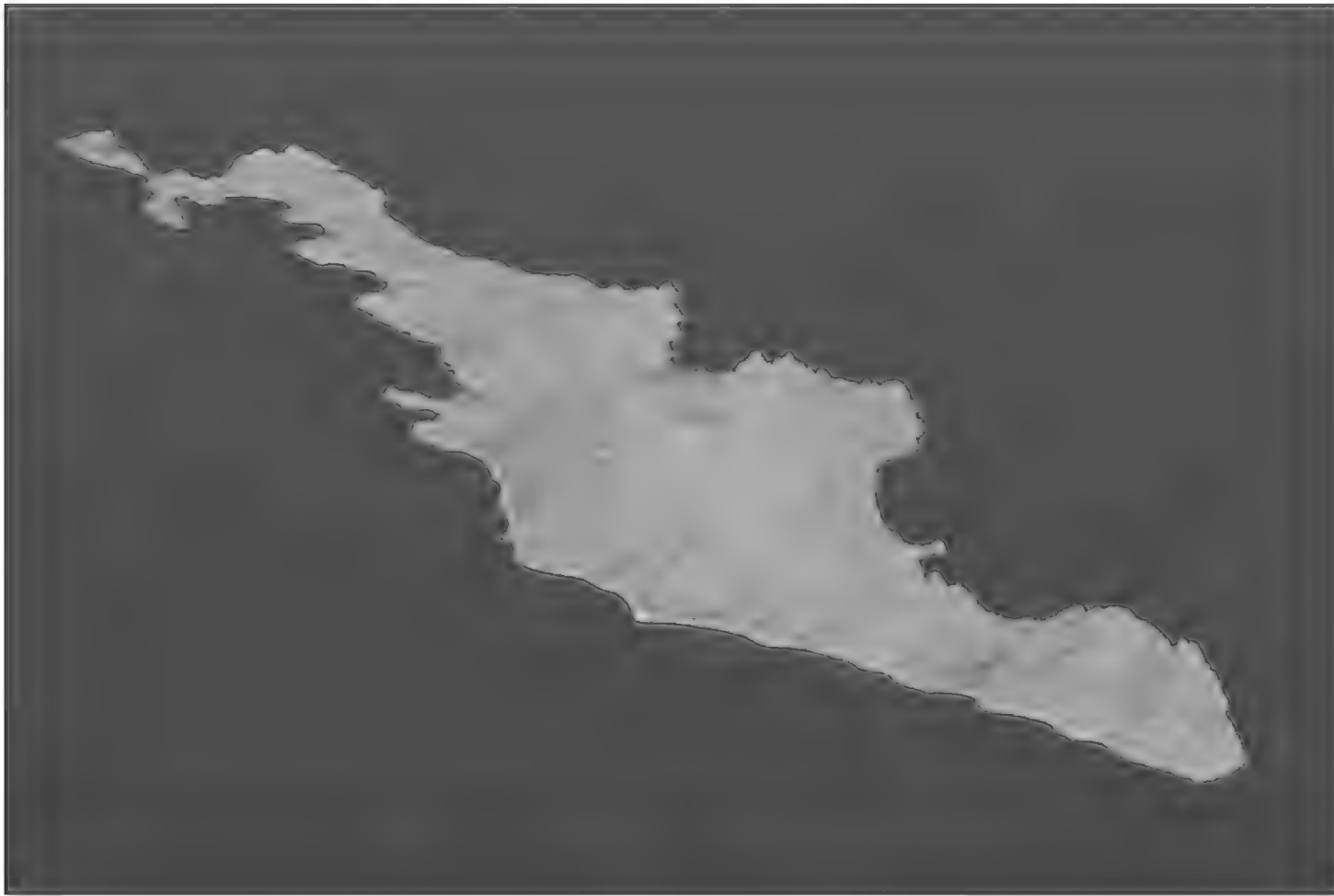


**Fig. 21.** View of Isla Carmen, Gulf of California, protected within Parque Nacional Bahía de Loreto. Photo by Bradford D. Hollingsworth.



**Fig. 22.** View of the uninhabited Isla Santa Catalina, also known as Catalana Island, located in the Gulf of California off the coast of Loreto, Baja California Sur, which is protected within Parque Nacional Bahía de Loreto and home to some of the most vulnerable species, including nine single-region endemics. Photo by Bradford D. Hollingsworth.





**Fig. 23.** Aerial view of the uninhabited Isla Danzante, which is protected within Parque Nacional Bahía de Loreto, with cliffs up to 150 m, representing the rugged topography typical of islands in the Gulf Island Region. *Photo by Bradford D. Hollingsworth.*

Among the 10 geographic regions of the Baja California Peninsula, the minimum annual temperatures range from 2.2 °C at Laguna Hanson in the Baja California Coniferous Forest to 17.8 °C in three localities: Santo Tomas (180 m) in the California Region, Loreto (20 m) in the Central Gulf Coast Region, and El Barril (50 m) in the Gulf Islands Region.

The minimum monthly temperatures peak in either July (Baja California Coniferous Forest Region), August (California Region, Lower Colorado Valley Region, Vizcaíno Region, Central Gulf Coast Region, Magdalena Region, Arid Tropical Region, Sierra La Laguna Region, and Gulf Islands Region), or August and September (Pacific Islands Region). The minimum monthly temperatures reach their lowest levels in either January (California, Lower Colorado Valley, Baja California Coniferous Forest, Central Gulf Coast, Magdalena, Arid Tropical, Sierra La Laguna, Pacific Islands, and Gulf Islands regions) or December and January (Vizcaíno region).

The maximum monthly temperatures are highest in either July (Lower Colorado Valley and Baja California Coniferous Forest regions), August (California, Vizcaíno, Central Gulf Coast, Magdalena, Arid Tropical, Sierra La Laguna, and Gulf Islands regions), or September (Pacific Islands region), and are lowest in either January (California, Lower Colorado Valley, Baja California Coniferous Forest, Central Gulf Coast, Magdalena, Arid Tropical, Sierra La Laguna, Pacific Islands, and Gulf Islands regions) or December and January (Vizcaíno region).

**Precipitation.** The patterns of precipitation in the Baja California Peninsula are peculiar compared to those

of other regions in Mexico. Whereas the rainy and dry seasons are confined to specific sets of six months during the year in most areas of Mexico, the rainy season in the Baja California Peninsula is comprised of no more than three or four months. In addition, the months involved are not the same throughout the Peninsula, and are not necessarily sequential.

Table 2 provides the precipitation data for 10 localities within each of the 10 geographic regions that we recognize in the peninsula, including the Pacific and Gulf islands. The rainy season extends for three months in the Lower Colorado Valley, the Baja California Coniferous Forest, the Central Gulf Coast, the Magdalena Region, and the Pacific Islands; while it extends for four months in the other five regions. The months involved in the 3-month regions are August through October (in the Lower Colorado Valley, the Central Gulf Coast, and the Magdalena Region), January through March (in the Baja California Coniferous Forest), and December through February (in the Pacific Islands). Those included in the 4-month regions are December through March (in the California Region), September through December (in the Vizcaíno Region), August through November (in the Arid Tropical Region), July through October (in the Sierra La Laguna Region), and August through October plus December (in the Gulf Islands).

The annual precipitation ranges from 52.2 mm in the Pacific Islands to 581.8 mm in the Sierra La Laguna Region. The mean annual precipitation for the 10 regions is 211.3 mm. The six annual precipitation values lying below this mean are for the Lower Colorado Valley (60.8 mm), the Vizcaíno Region (86.0 mm), the Central Gulf Coast Region (160.0 mm), the Magdalena Region (127.0 mm), the Pacific Islands (52.2 mm), and the Gulf Islands

**Table 1.** Monthly minimum, mean (in parentheses), maximum, and annual temperature data (in °C) for the 10 geographic regions of the Baja California Peninsula, Mexico. Localities in each region and their elevations are as follows: California, Santo Tomas (180 m); Lower Colorado Valley, El Mayor (15 m); Baja California Coniferous Forest, Laguna Hanson (1,580 m); Vizcaino, Benito Juarez (55 m); Central Gulf Coast, Loreto (20 m); Magdalena, La Purisima (95 m); Arid Tropical, San José del Cabo (20 m); Sierra La Laguna, San Vicente de la Sierra (650 m); Pacific Islands, Isla Cedros (3 m); and Gulf Islands, El Barril (50 m). Data were taken from Servicio Meteorológico Nacional at <https://smn.conagua.gob.mx> (accessed 18 July 2022).

Physiographic region	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
California	3.5 (12.2) 20.9	4.6 (13.0) 21.3	5.7 (14.0) 22.3	7.2 (16.0) 24.7	9.5 (18.3) 27.1	11.2 (20.9) 30.6	13.6 (24.1) 34.6	14.3 (24.6) 34.8	13.3 (23.6) 34.0	9.5 (19.5) 29.5	5.6 (15.2) 24.8	3.3 (12.4) 21.5	17.8 (17.8) 27.2
Lower Colorado Valley	4.9 (12.6) 20.2	6.6 (14.1) 21.6	8.5 (16.3) 24.2	10.4 (18.7) 27	13 (23.8) 34.6	16.1 (28.6) 41	19.3 (31.3) 43.4	19.8 (31.3) 42.9	17.5 (28.6) 39.6	13.2 (23) 32.9	8.8 (17.1) 25.5	5.2 (12.8) 20.4	11.9 (21.5) 31.1
Baja California Coniferous Forest	-2.7 (4.5) 11.7	-2.3 (5.4) 13.1	-1.6 (5.7) 12.9	0 (8.0) 16	2.7 (11.5) 20.3	5.6 (15.1) 24.6	9.5 (19.0) 28.4	9.1 (18.5) 27.9	7.1 (16.2) 25.4	2.2 (11.1) 20	-0.8 (7.4) 15.7	-2.4 (5.4) 13.4	2.2 (10.7) 19.1
Vizcaino	6.4 (16.4) 26.4	7.3 (17.2) 27.1	8.8 (18.3) 27.9	10.2 (19.5) 28.8	12.0 (20.6) 29.2	13.5 (22.1) 30.7	16.1 (25.1) 34.2	17.5 (26.6) 35.7	17.0 (25.9) 34.9	13.6 (22.9) 32.2	9.5 (19.5) 29.4	6.9 (16.7) 26.4	11.6 (20.9) 30.2
Central Gulf Coast	11.0 (17.2) 23.5	11.2 (17.9) 24.6	12.4 (19.3) 26.3	14.6 (21.8) 28.9	17.6 (24.7) 31.8	21.8 (28.2) 34.6	25.6 (30.7) 35.8	26.0 (31.1) 36.1	24.8 (30.2) 35.5	20.7 (26.9) 33.1	15.8 (22.0) 28.3	12.2 (18.3) 24.4	17.8 (24.0) 30.2
Magdalena	8.6 (17.7) 26.8	9.0 (18.5) 28.0	9.8 (19.5) 29.2	10.6 (20.7) 30.7	12.3 (22.0) 31.8	15.2 (24.7) 34.2	20.1 (28.6) 37.2	21.5 (29.6) 37.7	20.8 (28.9) 37.1	15.9 (25.2) 34.4	11.7 (21.2) 30.7	9.5 (18.4) 27.3	13.8 (22.9) 32.1
Arid Tropical	12.0 (18.9) 25.8	12.0 (19.2) 26.4	12.8 (20.1) 27.4	14.8 (21.9) 29.1	17.1 (24.0) 30.9	20.5 (26.5) 32.6	23.3 (28.5) 33.8	23.8 (28.9) 33.9	23.0 (28.2) 33.4	20.1 (26.2) 32.3	16.3 (23.2) 30.1	13.4 (20.2) 26.9	17.4 (23.8) 30.2
Sierra La Laguna	6.4 (15.7) 24.9	7.2 (16.5) 25.8	8.4 (17.7) 27.1	10.9 (21.0) 31.1	13.9 (23.6) 33.3	16.5 (25.8) 35.2	19.4 (27.9) 36.4	19.8 (27.9) 36.6	18.1 (26.2) 34.4	16.0 (24.6) 33.2	11.7 (20.7) 29.7	8.2 (17.4) 26.6	13.0 (22.1) 31.1
Pacific Islands	14.3 (18.6) 22.8	14.7 (19.1) 23.4	14.7 (19.2) 23.6	15.7 (20.5) 25.3	16.3 (21.0) 25.7	17.3 (21.7) 26.2	19.4 (24.0) 28.6	20.5 (24.9) 29.4	20.5 (25.0) 29.5	19.1 (23.8) 28.6	17.0 (21.4) 25.7	15.1 (19.2) 23.2	17.1 (21.5) 26.0
Gulf Islands	10.8 (16.4) 21.9	11.5 (17.3) 23.1	12.8 (18.8) 24.7	15.0 (21.0) 27.1	17.7 (23.6) 29.5	22.0 (27.7) 33.4	26.0 (30.7) 35.4	26.3 (30.8) 35.4	24.8 (29.8) 34.7	20.1 (25.8) 31.4	14.8 (20.6) 26.4	11.4 (17.0) 22.6	17.8 (23.3) 28.8

(91.6 mm). The four values lying above this mean are for the California Region (274.9 mm), the Baja California Coniferous Forest (390.9 mm), the Arid Tropical Region (288.0 mm), and the Sierra La Laguna Region (581.8 mm).

The percentages of annual precipitation that occur during the rainy season are as follows:

- California Region:  $210.8/274.9 = 76.7\%$  (4-month rainy season)
- Lower California Valley:  $27.4/60.8 = 45.1\%$  (3-month)
- Baja California Coniferous Forest:  $176.4/390.9 = 45.1\%$  (3-month)
- Vizcaino Region:  $47.8/86.0 = 55.6\%$  (4-month)
- Central Gulf Coast Region:  $111.9/160.0 = 69.9\%$  (3-month)
- Magdalena Region:  $66.1/127.0 = 52.0\%$  (3-month)
- Arid Tropical Region:  $209.0/288.0 = 72.6\%$  (4-month)
- Sierra La Laguna Region:  $519.9/581.8 = 89.4\%$  (4-month)
- Pacific Islands:  $30.0/52.2 = 57.5\%$  (3-month)
- Gulf Islands:  $67.4/91.6 = 73.6\%$  (4-month)

The range of percentages for the 3-month rainy seasons is 45.1–69.9% while it is 55.6–89.4% for the 4-month rainy seasons.

## Composition of the Herpetofauna

### Families

The members of the native and non-native herpetofauna of the Baja California Peninsula and its adjacent islands (hereinafter “the Baja California Peninsula” or simply “the peninsula”) are assigned to 32 families, including five families of anurans, one of salamanders, 20 of squamates, and six of turtles (Table 3). The total comprises 51.6% of the 62 families of native and non-native species found in Mexico. No crocodylian or caecilian families are represented on the peninsula. Of the six amphibian families represented on the peninsula, 85.7% of the 21 species (Tables 4 and 5) are placed in the families Bufonidae (six species), Hylidae (three), Ranidae (six), and Plethodontidae (three). Among the 26 reptilian families, 122 of the 151 species (80.8%) are allocated in the families Crotophytidae (five species), Iguanidae (nine), Phrynosomatidae (30), Phyllodactylidae (five),

**Table 2.** Monthly and annual precipitation data (in mm) for the 10 geographic regions of the Baja California Peninsula, Mexico. Localities in each region and their elevations are as follows: California, Santo Tomas (180 m); Lower Colorado Valley, El Mayor (15 m); Baja California Coniferous Forest, Laguna Hanson (1,580 m); Vizcaíno, Benito Juárez (55 m); Central Gulf Coast, Loreto (20 m); Magdalena, La Purísima (95 m); Arid Tropical, San José del Cabo (20 m); Sierra La Laguna, San Vicente de la Sierra (650 m); Pacific Islands, Isla Cedros (3 m); and Gulf Islands, El Barril (50 m). Data were taken from Servicio Meteorológico Nacional at <https://smn.conagua.gob.mx> (accessed 18 July 2022). Shaded areas indicate the months of the rainy season in each region.

Physiographic region	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
California	60.3	60.1	51.8	19.4	2.6	0.3	1.4	2.5	3.6	9.8	24.5	38.6	274.9
Lower Colorado Valley	6.0	6.8	5.0	2.2	0.0	0.3	3.2	9.4	10.3	7.7	3.1	6.8	60.8
Baja California Coniferous Forest	51.1	57.0	68.3	22.9	3.9	0.5	33.8	39.9	21.5	17.8	38.1	36.1	390.9
Vizcaíno	8.9	12.4	7.0	0.7	0.2	0.0	3.0	6.0	9.7	6.5	8.6	23.0	86.0
Central Gulf Coast	12.3	5.0	1.4	0.0	0.2	0.4	7.1	36.6	56.6	18.7	7.4	14.3	160.0
Magdalena	12.3	8.4	3.5	0.6	0.2	0.1	8.8	26.9	27.1	12.1	7.3	19.7	127.0
Arid Tropical	13.1	5.3	1.3	1.0	0.3	0.9	20.5	53.6	112.5	42.9	25.2	11.4	288.0
Sierra La Laguna	14.6	11.4	2.3	0.0	0.0	3.1	39.3	155.9	303.7	21.0	16.3	14.2	581.8
Pacific Islands	9.5	11.2	4.9	1.7	0.6	0.1	0.2	0.7	3.1	6.1	4.8	9.3	52.2
Gulf Islands	6.1	6.1	2.1	0.2	0.2	0.4	5.2	18.8	25.9	9.5	3.4	13.7	91.6

Teiidae (13), Xantusiidae (four), Colubridae (29), Dipsadidae (seven), Natricidae (four), Viperidae (12), and Cheloniidae (four).

Genera

Representatives of 64 herpetofaunal genera have been recorded from the Baja California Peninsula, including nine genera of anurans, three of caudates, 42 of squamates, and 10 of turtles (Table 3). These 64 taxa comprise 30.0% of the 213 genera that occur in Mexico (J. Johnson, unpub. data, 27 May 2023). Among the amphibians, the largest numbers of species in Baja California are in the genera *Anaxyrus* (five species) and *Lithobates* (four); and among reptiles the largest numbers are in the genera *Elgaria* (five), *Sauromalus* (five), *Petrosaurus* (four), *Phrynosoma* (five), *Sceloporus* (10), *Urosaurus* (four), *Uta* (five), *Phyllodactylus* (five), *Aspidoscelis* (13), *Xantusia* (four), *Lampropeltis* (four), *Masticophis* (five), *Sonora* (eight), *Hypsiglena* (six), *Thamnophis* (four), and *Crotalus* (12).

Species

The herpetofauna of the Baja California Peninsula consists of 172 species, including 18 anurans, three salamanders, 140 squamates, and 11 turtles (Table 3). The current numbers of native species in these four groups in Mexico are 272, 161, 913, and 51, respectively (J. Johnson, unpub. data, 27 May 2023). The 172 herpetofaunal species known from the Baja California Peninsula represent 12.3% of the 1,397 species of anurans, salamanders, squamates, and turtles in the entire country (J. Johnson, unpub. data, 27 May 2023). The only Mexican state that shares a border with the peninsula is Sonora, and that border is limited in extent. Rorabaugh and Lemos Espinal (2016) reported the number of herpetofaunal species in Sonora as 196, which is 1.1 times the size of the herpetofauna of the peninsula. This proportion is similar to the relative areas of the two regions. The surface area of Sonora is 185,430 km<sup>2</sup> (Rorabaugh and Lemos Espinal 2016) and that of the Baja California Peninsula is approximately 143,400 km<sup>2</sup>; thus, Sonora is about 1.3 times the size of the entire peninsula. Therefore, the area/species richness ratios are 828.9 for the peninsula and 946.1 for Sonora.

Fourteen non-native species comprise 8.1% of total herpetofauna (172 species) of the Baja California Peninsula, and each of the two states contains nine non-native species and share four species. This is the highest number so far in our series of Mexican state herpetofaunas, with an average of four non-natives. Of the 14 non-native species in the Peninsula, five are amphibians, and nine are reptiles (three geckos, two iguanas, one snake, and three turtles), including two species that were listed among the 100 worst invasive alien species (*Lithobates catesbeianus* and *Trachemys scripta*) (Lowe et al. 2000).



**Table 3.** Composition of the native and non-native herpetofauna of the Baja California Peninsula and its adjacent islands, Mexico.

Order	Families	Genera	Species
Anura	5	9	18
Caudata	1	3	3
<b>Subtotal</b>	<b>6</b>	<b>12</b>	<b>21</b>
Squamata	20	42	140
Testudines	6	10	11
<b>Subtotal</b>	<b>26</b>	<b>52</b>	<b>151</b>
<b>Total</b>	<b>32</b>	<b>64</b>	<b>172</b>

Patterns of Geographic Distribution

We adopted the principal features of the scheme of geographic regions used by Grismer (2002). However, we departed from this system to some extent, in that we recognize the insular regions as separate from the peninsular regions (Table 4). Thus, we recognize eight regions on the peninsula and two regions among the islands (Pacific and Gulf). The distributional data for the 172 species are tabulated in Table 4, and summarized in Table 5.

The total number of species in each of the 10 regions (Table 5) ranges from 27 in the Baja California Coniferous Forest Region (BCCFR) to 84 in the Gulf Islands Region (GIR). The average number of regional species is 56.9. The sizes of the herpetofaunas in six of the regions (CR, LCVR, VR, CGCR, ATR, and GIR) are above this average value, and in four (BCCFR, MR, SLLR, and PIR) they are below it. The respective sizes of the regional herpetofaunas do not appear to be related to the relative sizes of the regions themselves, especially since the largest herpetofauna is found on the islands of the Gulf Region. We will examine this issue in greater detail after we present the subsequent analyses.

The amphibian fauna of the peninsula is comprised of only 21 species (18 anurans and three salamanders), or 12.2% of the total of 172 species. Thus, 87.8% of the total are reptiles. Relatively few of the 151 species of reptiles are turtles, i.e., 11 species (7.3%). Therefore, most of the herpetofaunal species found in the peninsula are squamates, viz., 140 species, or 81.4% of the total of 172. This result is reasonable, given that the general climate of the peninsula is arid and that much of the diversity of the herpetofauna is insular in distribution (see below). Of the 140 squamate species, 83 (59.3%) are lizards and 57 (40.7%) are snakes. Consequently, the peninsula is a hotspot for lizards, since the 83 species comprise 48.3% of the total herpetofauna.

The proportion of the total herpetofauna of 172 species found in each of the 10 regions ranges from 15.9% (27 species in the BCCFR) to 48.8% (84 in the GIR), which indicates the limited extent of species distributions on the peninsula.

The members of the peninsular herpetofauna occur in from one to 10 regions as follows: one region (78 of 172 species, 45.3%); two regions (16, 9.3%); three (17, 9.9%); four (10, 5.8%); five (13, 7.6%); six (seven, 4.1%); seven (six, 3.5%); eight (12, 7.0%); nine (7,

4.1%), and 10 (six, 3.5%). The mean regional occupancy is 3.3. This figure lies within the range of 1.6 to 3.7 for the other states dealt with thus far in the MCS (Alvarado-Díaz et al. 2013; Mata-Silva et al. 2015; Johnson et al. 2015; Terán-Juárez et al. 2016; Woolrich-Piña et al. 2016; Nevárez-de los Reyes et al. 2016; Cruz-Sáenz et al. 2017; González-Sánchez et al. 2017; Lazcano et al. 2019; Ramírez-Bautista et al. 2020; Torres-Hernández et al. 2021; Cruz-Elizalde et al. 2022). Of the 172 species known from the peninsula, a relatively large proportion (45.3%) is confined to a single region, which is highly significant from a conservation perspective (see below). The number of single-region species ranges from one (in the MR) to 39 (in the GIR).

The 39 single-region species in the GIR are as follows, with species endemic to the peninsula indicated by double asterisks, and non-natives indicated by triple asterisks:

- Crotaphytus insularis*\*\*
- Coleonyx gypsicolus*\*\*
- Dipsosaurus catalinensis*\*\*
- Sauromalus hispidus*\*\*
- Sauromalus klauberi*\*\*
- Sauromalus slevini*\*\*
- Sauromalus varius*\*\*\*
- Petrosaurus slevini*\*\*
- Sceloporus angustus*\*\*
- Sceloporus grandaevus*\*\*
- Sceloporus lineatulus*\*\*
- Uta encantadae*\*\*
- Uta lowei*\*\*
- Uta squamata*\*\*
- Uta tumidarostra*\*\*
- Phyllodactylus bugastrolepis*\*\*
- Phyllodactylus partidus*\*\*
- Aspidoscelis canus*\*\*
- Aspidoscelis carmenensis*\*\*
- Aspidoscelis catalinensis*\*\*
- Aspidoscelis celeripes*\*\*
- Aspidoscelis ceralbensis*\*\*
- Aspidoscelis danheimae*\*\*
- Aspidoscelis espiritensis*\*\*
- Aspidoscelis franciscensis*\*\*
- Aspidoscelis pictus*\*\*
- Lampropeltis catalinensis*\*\*
- Masticophis barbouri*\*\*
- Rhinocheilus etheridgei*\*\*

## The herpetofauna of the Baja California Peninsula

**Table 4.** Distribution of amphibians and reptiles in the Baja California Peninsula and its adjacent islands, Mexico, by geographic province. Abbreviations: CR = California Region; LCVR = Lower Colorado Valley Region; BCCFR = Baja California Coniferous Forest Region; VR = Vizcaíno Region; CGCR = Central Gulf Coast Region; MR = Magdalena Region; ATR = Arid Tropical Region; SLLR = Sierra La Laguna Region; PIR = Pacific Islands Region; and GIR = Gulf Islands Region. \* = species endemic to Mexico; \*\* = species endemic to Baja California; \*\*\* = non-native.

Taxon	Geographic regions of the Peninsula of Baja California and its adjacent islands										Number of regions occupied
	CR	LCVR	BCCFR	VR	CGCR	MR	ATR	SLLR	PIR	GIR	
<b>Anura (18 species)</b>											
<b>Bufonidae (6 species)</b>											
<i>Anaxyrus boreas</i>	+	+	+	+							4
<i>Anaxyrus californicus</i>	+										1
<i>Anaxyrus cognatus</i>		+									1
<i>Anaxyrus punctatus</i>		+		+	+	+	+	+	+	+	8
<i>Anaxyrus woodhousii</i>		+									1
<i>Incilius alvarius</i>		+									1
<b>Hylidae (3 species)</b>											
<i>Pseudacris cadaverina</i>	+	+		+							3
<i>Pseudacris hypochondriaca</i>	+	+	+	+	+	+	+	+	+		9
<i>Smilisca baudinii</i> ***							+				1
<b>Pipidae (1 species)</b>											
<i>Xenopus laevis</i> ***	+										1
<b>Ranidae (6 species)</b>											
<i>Lithobates berlandieri</i> ***		+									1
<i>Lithobates catesbeianus</i> ***	+	+		+	+			+			5
<i>Lithobates forreri</i> ***					+		+				2
<i>Lithobates yavapaiensis</i>		+									1
<i>Rana boylei</i>			+								1
<i>Rana draytonii</i>	+		+								2
<b>Scaphiopodidae (2 species)</b>											
<i>Scaphiopus couchii</i>		+		+	+	+	+	+		+	7
<i>Spea hammondi</i>	+			+							2
<b>Caudata (3 species)</b>											
<b>Plethodontidae (3 species)</b>											
<i>Aneides lugubris</i>	+								+		2
<i>Batrachoseps major</i>	+		+						+		3
<i>Ensatina eschscholtzii</i>	+		+								2
<b>Squamata (140 species)</b>											
<b>Anguidae (5 species)</b>											
<i>Elgaria cedrosensis</i> **									+		1
<i>Elgaria multicarinata</i>	+		+	+					+		4
<i>Elgaria nana</i> **									+		1
<i>Elgaria paucicarinata</i> **					+		+	+			3
<i>Elgaria velazquezii</i> **				+	+	+	+				4
<b>Anniellidae (2 species)</b>											
<i>Anniella geronimensis</i> **	+			+					+		3
<i>Anniella stebbinsi</i>	+								+		2
<b>Bipedidae (1 species)</b>											
<i>Bipes biporus</i> **				+	+	+	+		+		5
<b>Crotaphytidae (5 species)</b>											
<i>Crotaphytus grismeri</i> **		+									1
<i>Crotaphytus insularis</i> **										+	1
<i>Crotaphytus vestigium</i>	+	+		+	+	+	+				6
<i>Gambelia copeii</i> **	+	+		+	+	+	+		+		7
<i>Gambelia wislizenii</i>		+									1
<b>Eublepharidae (3 species)</b>											
<i>Coleonyx gypsicolus</i> **										+	1
<i>Coleonyx switaki</i>		+		+	+						3
<i>Coleonyx variegatus</i>	+	+		+	+	+	+	+	+	+	9
<b>Gekkonidae (3 species)</b>											
<i>Gehyra mutilata</i> ***							+				1

**Table 4 (continued).** Distribution of amphibians and reptiles in the Baja California Peninsula and its adjacent islands, Mexico, by geographic province. Abbreviations: CR = California Region; LCVR = Lower Colorado Valley Region; BCCFR = Baja California Coniferous Forest Region; VR = Vizcaino Region; CGCR = Central Gulf Coast Region; MR = Magdalena Region; ATR = Arid Tropical Region; SLLR = Sierra La Laguna Region; PIR = Pacific Islands Region; and GIR = Gulf Islands Region. \* = species endemic to Mexico; \*\* = species endemic to Baja California; \*\*\* = non-native.

Taxon	Geographic regions of the Peninsula of Baja California and its adjacent islands										Number of regions occupied
	CR	LCVR	BCCFR	VR	CGCR	MR	ATR	SLLR	PIR	GIR	
<i>Hemidactylus frenatus</i> ***				+	+	+	+	+		+	6
<i>Hemidactylus turcicus</i> ***	+	+									2
<b>Iguanidae (9 species)</b>											
<i>Ctenosaura hemilopha</i> **					+	+	+	+		+	5
<i>Dipsosaurus catalinensis</i> **										+	1
<i>Dipsosaurus dorsalis</i>		+		+	+	+	+	+	+	+	8
<i>Iguana rhinolopha</i> ***							+				1
<i>Sauromalus ater</i>		+		+	+	+	+			+	6
<i>Sauromalus hispidus</i> **										+	1
<i>Sauromalus klauberi</i> **										+	1
<i>Sauromalus slevini</i> **										+	1
<i>Sauromalus varius</i> ***										+	1
<b>Phrynosomatidae (30 species)</b>											
<i>Callisaurus draconoides</i>	+	+		+	+	+	+	+	+	+	9
<i>Petrosaurus mearnsi</i>	+	+		+						+	4
<i>Petrosaurus repens</i> **				+	+	+	+			+	5
<i>Petrosaurus slevini</i> **										+	1
<i>Petrosaurus thalassinus</i> **							+	+		+	3
<i>Phrynosoma blainvillii</i>	+										1
<i>Phrynosoma cerroense</i> **	+			+	+	+			+		5
<i>Phrynosoma coronatum</i> **					+	+	+	+			4
<i>Phrynosoma mcallii</i>		+									1
<i>Phrynosoma platyrhinos</i>		+									1
<i>Sceloporus angustus</i> **										+	1
<i>Sceloporus grandaevus</i> **										+	1
<i>Sceloporus hunsakeri</i> **							+	+		+	3
<i>Sceloporus licki</i> **							+	+			2
<i>Sceloporus lineatulus</i> **										+	1
<i>Sceloporus magister</i>		+									1
<i>Sceloporus occidentalis</i>	+		+						+		3
<i>Sceloporus orcutti</i>	+	+	+	+	+	+	+			+	8
<i>Sceloporus vandenburgianus</i>			+								1
<i>Sceloporus zosteromus</i> **	+			+	+	+	+	+	+	+	8
<i>Uma notata</i>		+									1
<i>Urosaurus graciosus</i>		+									1
<i>Urosaurus lahtelai</i> **				+							1
<i>Urosaurus nigricaudus</i>	+	+		+	+	+	+	+	+	+	9
<i>Urosaurus ornatus</i>		+									1
<i>Uta encantadae</i> **										+	1
<i>Uta lowei</i> **										+	1
<i>Uta squamata</i> **										+	1
<i>Uta stansburiana</i>	+	+	+	+	+	+	+	+	+	+	10
<i>Uta tumidarostrea</i> **										+	1
<b>Phyllodactylidae (5 species)</b>											
<i>Phyllodactylus bugastrolepis</i> **										+	1
<i>Phyllodactylus nocticolus</i>	+	+		+	+	+	+		+	+	8
<i>Phyllodactylus partidus</i> **										+	1
<i>Phyllodactylus unctus</i> **					+		+	+		+	4
<i>Phyllodactylus xanti</i> **					+		+	+			3
<b>Scincidae (3 species)</b>											
<i>Plestiodon gilberti</i>	+	+	+								3
<i>Plestiodon lagunensis</i> **				+	+	+	+	+			5
<i>Plestiodon skiltonianus</i>	+		+						+		3



## The herpetofauna of the Baja California Peninsula

**Table 4 (continued).** Distribution of amphibians and reptiles in the Baja California Peninsula and its adjacent islands, Mexico, by geographic province. Abbreviations: CR = California Region; LCVR = Lower Colorado Valley Region; BCCFR = Baja California Coniferous Forest Region; VR = Vizcaino Region; CGCR = Central Gulf Coast Region; MR = Magdalena Region; ATR = Arid Tropical Region; SLLR = Sierra La Laguna Region; PIR = Pacific Islands Region; and GIR = Gulf Islands Region. \* = species endemic to Mexico; \*\* = species endemic to Baja California; \*\*\* = non-native.

Taxon	Geographic regions of the Peninsula of Baja California and its adjacent islands										Number of regions occupied
	CR	LCVR	BCCFR	VR	CGCR	MR	ATR	SLLR	PIR	GIR	
<b>Teiidae (13 species)</b>											
<i>Aspidoscelis canus</i> **										+	1
<i>Aspidoscelis carmenensis</i> **										+	1
<i>Aspidoscelis catalinensis</i> **										+	1
<i>Aspidoscelis celeripes</i> **										+	1
<i>Aspidoscelis ceralbensis</i> **										+	1
<i>Aspidoscelis danheimae</i> **										+	1
<i>Aspidoscelis espiritensis</i> **										+	1
<i>Aspidoscelis franciscensis</i> **										+	1
<i>Aspidoscelis hyperythrus</i>	+			+	+	+	+	+	+	+	8
<i>Aspidoscelis labialis</i> **	+			+							2
<i>Aspidoscelis maximus</i> **					+		+	+		+	4
<i>Aspidoscelis pictus</i> **										+	1
<i>Aspidoscelis tigris</i>	+	+		+	+	+	+		+	+	8
<b>Xantusiidae (4 species)</b>											
<i>Xantusia gilberti</i> **								+			1
<i>Xantusia henshawi</i>	+		+								2
<i>Xantusia sherbrookei</i> **						+					1
<i>Xantusia wigginsi</i>	+	+		+	+						4
<b>Charinidae (1 species)</b>											
<i>Lichanura trivirgata</i>	+	+		+	+	+	+	+	+	+	9
<b>Colubridae (29 species)</b>											
<i>Arizona elegans</i>	+	+		+							3
<i>Arizona pacata</i> **				+		+					2
<i>Bogertophis rosaliae</i>		+		+	+	+	+	+		+	7
<i>Lampropeltis californiae</i>	+	+	+	+	+	+	+	+	+	+	10
<i>Lampropeltis catalinensis</i> **										+	1
<i>Lampropeltis herrerae</i> **									+		1
<i>Lampropeltis multifasciata</i>			+								1
<i>Masticophis aurigulus</i> **					+		+	+			3
<i>Masticophis barbouri</i> **										+	1
<i>Masticophis flagellum</i>		+									1
<i>Masticophis fuliginosus</i>	+	+	+	+	+	+	+	+	+	+	10
<i>Masticophis lateralis</i>	+	+	+	+	+	+					6
<i>Phyllorhynchus decurtatus</i>		+		+	+	+	+			+	6
<i>Pituophis catenifer</i>	+	+	+	+					+		5
<i>Pituophis insulanus</i> **									+		1
<i>Pituophis vertebralis</i> **	+			+	+	+	+	+	+	+	8
<i>Rhinocheilus etheridgei</i> **										+	1
<i>Rhinocheilus lecontei</i>	+	+		+							3
<i>Salvadora hexalepis</i>	+	+	+	+	+	+	+	+	+	+	10
<i>Sonora annulata</i>		+									1
<i>Sonora cincta</i> **	+	+		+	+				+		5
<i>Sonora fasciata</i> **					+	+	+		+	+	5
<i>Sonora mosaueri</i> **				+	+	+	+				4
<i>Sonora punctatissima</i> **										+	1
<i>Sonora savagei</i> **										+	1
<i>Sonora straminea</i> **					+		+	+			3
<i>Sonora semiannulata</i>		+									1
<i>Tantilla planiceps</i>	+	+		+	+	+	+	+		+	8
<i>Trimorphodon lyrophanes</i>	+	+	+	+	+	+	+	+		+	9

**Table 4 (continued).** Distribution of amphibians and reptiles in the Baja California Peninsula and its adjacent islands, Mexico, by geographic province. Abbreviations: CR = California Region; LCVR = Lower Colorado Valley Region; BCCFR = Baja California Coniferous Forest Region; VR = Vizcaino Region; CGCR = Central Gulf Coast Region; MR = Magdalena Region; ATR = Arid Tropical Region; SLLR = Sierra La Laguna Region; PIR = Pacific Islands Region; and GIR = Gulf Islands Region. \* = species endemic to Mexico; \*\* = species endemic to Baja California; \*\*\* = non-native.

Taxon	Geographic regions of the Peninsula of Baja California and its adjacent islands										Number of regions occupied
	CR	LCVR	BCCFR	VR	CGCR	MR	ATR	SLLR	PIR	GIR	
<b>Dipsadidae (7 species)</b>											
<i>Diadophis punctatus</i>	+								+		2
<i>Hypsiglena catalinae</i> **										+	1
<i>Hypsiglena chlorophaea</i>		+									1
<i>Hypsiglena gularis</i> **										+	1
<i>Hypsiglena marcosensis</i> **										+	1
<i>Hypsiglena ochrorhynchus</i>	+	+	+	+	+	+	+	+	+	+	10
<i>Hypsiglena slevini</i> **		+		+	+	+	+	+	+	+	8
<b>Elapidae (1 species)</b>											
<i>Hydrophis platurus</i>		+			+	+	+		+	+	6
<b>Leptotyphlopidae (2 species)</b>											
<i>Rena boettgeri</i> **					+		+	+			3
<i>Rena humilis</i>	+	+		+	+	+	+		+	+	8
<b>Natricidae (4 species)</b>											
<i>Thamnophis elegans</i>			+								1
<i>Thamnophis hammondi</i>	+		+	+	+	+	+				6
<i>Thamnophis marcianus</i>		+									1
<i>Thamnophis validus</i> **							+	+			2
<b>Typhlopidae (1 species)</b>											
<i>Indotyphlops braminus</i> ***	+			+			+				3
<b>Viperidae (12 species)</b>											
<i>Crotalus angelensis</i> **										+	1
<i>Crotalus atrox</i>		+								+	2
<i>Crotalus catalinensis</i> **										+	1
<i>Crotalus cerastes</i>		+			+						2
<i>Crotalus enyo</i> **	+	+		+	+	+	+	+	+	+	9
<i>Crotalus helleri</i>	+	+	+	+					+		5
<i>Crotalus lorenzoensis</i> **										+	1
<i>Crotalus mitchellii</i> **				+	+	+	+	+	+	+	7
<i>Crotalus polisi</i> **										+	1
<i>Crotalus pyrrhus</i>	+	+	+	+						+	5
<i>Crotalus ruber</i>	+	+	+	+	+	+	+	+	+	+	10
<i>Crotalus thalassoporus</i> **										+	1
<b>Testudines (11 species)</b>											
<b>Cheloniidae (4 species)</b>											
<i>Caretta caretta</i>	+	+		+	+	+			+	+	7
<i>Chelonia mydas</i>		+		+	+	+	+		+	+	7
<i>Eretmochelys imbricata</i>					+		+		+	+	4
<i>Lepidochelys olivacea</i>	+	+		+	+	+	+		+	+	8
<b>Dermochelyidae (1 species)</b>											
<i>Dermochelys coriacea</i>		+				+	+		+	+	5
<b>Emydidae (3 species)</b>											
<i>Actinemys pallida</i>	+			+							2
<i>Trachemys nebulosa</i> **				+	+	+	+	+			5
<i>Trachemys scripta</i> ***	+										1
<b>Kinosternidae (1 species)</b>											
<i>Kinosternon integrum</i> ***							+				1
<b>Testudinidae (1 species)</b>											
<i>Gopherus morafkai</i>							+				1
<b>Trionychidae (1 species)</b>											
<i>Apalone spinifera</i> ***		+									1
<b>Total (172 species)</b>											

The herpetofauna of the Baja California Peninsula

**Table 5.** Summary of distributional occurrence of herpetofaunal families in the Baja California Peninsula, Mexico, by geographic region. Abbreviations: CR = California Region; LCVR = Lower Colorado Valley Region; BCCFR = Baja California Coniferous Forest Region; VR = Vizcaíno Region; CGCR = Central Gulf Coast Region; MR = Magdalena Region; ATR = Arid Tropical Region; SLLR = Sierra La Laguna Region; PIR = Pacific Islands Region; and GIR = Gulf Islands Region.

Family	Number of species	Distributional occurrence									
		CR	LCVR	BCCFR	VR	CGCR	MR	ATR	SLLR	PIR	GIR
Bufonidae	6	2	5	1	2	1	1	1	1	1	1
Hylidae	3	2	2	1	2	1	1	2	1	1	—
Pipidae	1	1	—	—	—	—	—	—	—	—	—
Ranidae	6	2	3	2	1	2	—	1	1	—	—
Scaphiopodidae	2	1	1	—	2	1	1	1	1	—	1
Subtotal	18	8	11	4	7	5	3	5	4	2	2
Plethodontidae	3	3	—	2	—	—	—	—	—	2	—
Subtotal	3	3	—	2	—	—	—	—	—	2	
Total	21	11	11	6	7	5	3	5	4	4	2
Anguidae	5	1	—	1	2	2	1	2	1	3	—
Anniellidae	2	2	—	—	1	—	—	—	—	2	—
Bipedidae	1	—	—	—	1	1	1	1	—	1	—
Crotaphytidae	5	2	4	—	2	2	2	2	—	1	1
Eublepharidae	3	1	2	—	2	2	1	1	1	1	2
Gekkonidae	3	1	1	—	1	1	1	2	1	—	1
Iguanidae	9	—	2	—	2	3	3	4	2	1	8
Phrynosomatidae	30	9	11	4	9	8	8	10	8	6	17
Phyllodactylidae	5	1	1	—	1	3	1	3	2	1	4
Scincidae	3	2	1	2	1	1	1	1	1	1	—
Teiidae	13	3	1	—	3	3	2	3	2	2	12
Xantusiidae	4	2	1	1	1	1	1	—	1	—	—
Subtotal	83	24	24	8	26	27	22	29	19	19	45
Charinidae	1	1	1	—	1	1	1	1	1	1	1
Colubridae	29	11	15	7	15	14	12	12	9	9	14
Dipsadidae	7	2	3	1	2	2	2	2	2	3	5
Elapidae	1	—	1	—	—	1	1	1	—	1	1
Leptotyphlopidae	2	1	1	—	1	2	1	2	1	1	1
Natricidae	4	1	1	2	1	1	1	2	1	—	—
Typhlopidae	1	1	—	—	1	—	—	1	—	—	—
Viperidae	12	4	6	3	5	4	3	3	3	4	10
Subtotal	57	21	28	13	26	25	21	24	17	19	32
Cheloniidae	4	2	3	—	3	4	3	3	—	4	4
Dermochelyidae	1	—	1	—	—	—	1	1	—	1	1
Emydidae	3	2	—	—	2	1	1	1	1	—	—
Kinosternidae	1	—	—	—	—	—	—	1	—	—	—
Testudinidae	1	—	—	—	—	—	—	1	—	—	—
Trionychidae	1	—	1	—	—	—	—	—	—	—	—
Subtotal	11	4	5	—	5	5	5	7	1	5	5
Total	152	49	57	21	57	57	48	60	37	43	82
Sum total	172	60	68	27	64	62	51	65	41	47	84

- Sonora punctatissima*\*\*
- Sonora savagei*\*\*
- Hypsiglena catalinae*\*\*
- Hypsiglena gularis*\*\*
- Hypsiglena marcosensis*\*\*
- Crotalus angelensis*\*\*
- Crotalus catalinensis*\*\*
- Crotalus lorenzoensis*\*\*
- Crotalus polisi*\*\*
- Crotalus thalassoporus*\*\*

These species are all peninsular endemics, except for one (*Sauromalus varius*) which was introduced to a small islet included in the Gulf Island group (Hollingsworth et al. 1997). These species are all either lizards (26 species) or snakes (13 species).

The peninsular region with the next largest number of single-region species is the LCVR, with 19, as follows (the number following the species name indicates which of the distributional categories is involved):



*Anaxyrus cognatus* 3  
*Anaxyrus woodhousii* 3  
*Incilius alvarius* 3  
*Lithobates berlandieri*\*\*\*2  
*Lithobates yavapaiensis* 3  
*Crotaphytus grismeri*\*\*  
*Gambelia wislizenii* 3  
*Phrynosoma mcallii* 3  
*Phrynosoma platyrhinos* 3  
*Sceloporus magister* 3  
*Uma notata* 3  
*Urosaurus graciosus* 3  
*Urosaurus ornatus* 3  
*Masticophis flagellum* 3  
*Sonora annulata* 3  
*Sonora semiannulata* 3  
*Hypsiglena chlorophaea* 3  
*Thamnophis marcianus* 7  
*Apalone spinifera*\*\*\*

Of these 19 species, 16 (84.2%) are non-endemics, two are introduced species, and one is a peninsular endemic. Of the 16 non-endemic species, all but one are distributed to the north in the United States; and the single exception is the garter snake *Thamnophis marcianus*, which occurs from the United States through Mexico, and into Central America (<http://mesoamericanherpetology.com>; accessed 5 June 2022). *Crotaphytus grismeri* is endemic to the LCVR, and the two introduced species are from populations outside of Baja California.

The third-largest group of single-region species is found in the ATR region, and is comprised of the following five species:

*Smilisca baudinii*\*\*\*  
*Gehyra mutilata*\*\*\*  
*Iguana rhinolopha*\*\*\*  
*Kinosternon integrum*\*\*\*  
*Gopherus morafkai* 3

Interestingly, four of these five species are introduced, either from elsewhere in Mesoamerica or from outside of Mesoamerica; and the remaining species also is distributed in the United States.

Three regions contain four single-region species. One of these regions is the CR, and the species are as follows:

*Anaxyrus californicus* 3  
*Xenopus laevis*\*\*\*  
*Phrynosoma blainvillii* 3  
*Trachemys scripta*\*\*\*

Two of these species are non-native, and the other two also are distributed in the United States.

The second region with four single-region species is the BCCFR, and the species are as follows:

*Rana boylii* 3  
*Sceloporus vandenburgianus* 3  
*Lampropeltis multifasciata* 3  
*Thamnophis elegans* 3

All four of these species also are distributed to the north in the United States.

In significant contrast to the GIR, the PIR supports only four single-region species, as follows:

*Elgaria cedrosensis*\*\*  
*Elgaria nana*\*\*  
*Lampropeltis herrerae*\*\*  
*Pituophis insulanus*\*\*

All of these species are peninsular endemics, like most of the species in the GIR.

Three other regions contain only one single-region species. One is the MR, and the species involved is:

*Xantusia sherbrookei*\*\*

This species is a peninsular endemic.

The second region with one single-region species is the SLLR, and the species is:

*Xantusia gilberti*\*\*

It also is a peninsular endemic.

The last region with one single-region species is the VR, and the species is:

*Urosaurus lahtelai*\*\*

This species is another peninsular endemic.

In summary, of the 78 single-region species found on the peninsula, 46 are peninsular endemics, 23 are non-endemics, and nine are non-native species. Only one of the 10 regions, the CGCR, has no single-region species. Of the 10 phytogeographic regions on the peninsula, the GIR is the most significant with regard to conservation importance, since it contains the largest overall number of species (84), the largest number of single-region species (39), and the greatest number of peninsular endemics (50).

## Regional Occupancy and the Coefficient of Biogeographic Resemblance (CBR)

Another indication of conservation significance involving the 10 phytogeographic regions is the relative average regional occupancy (Table 6). This figure is calculated by recording the number of species occupying each of the regions 1 through 10. For example, the CR contains 60 species that occupy regions 1–10 as follows:

The herpetofauna of the Baja California Peninsula

**Table 6.** Numbers of species, regional occupancy, and average regional occupancy for the geographic regions of the Baja California Peninsula and adjacent islands, Mexico. See Table 4 for abbreviations.

Phytogeographic region	Number of species	Species regional occupancy										Total	Average regional occupancy
		1	2	3	4	5	6	7	8	9	10		
CR	60	4	20	30	12	30	24	14	64	63	60	321	5.4
LCVR	68	19	6	21	8	25	36	35	64	63	60	337	5.0
BCCFR	27	4	6	12	8	15	12	0	8	18	60	141	5.2
VR	64	0	10	24	20	45	42	42	88	63	60	394	6.2
CGCR	62	0	4	18	36	35	48	42	88	63	60	394	6.4
MR	51	1	2	6	16	25	48	42	88	63	60	351	6.9
ATR	65	5	6	27	32	20	42	35	88	63	60	378	5.8
SLLR	41	1	4	18	20	15	6	21	56	63	60	264	6.4
PIR	47	4	6	12	8	25	6	28	72	54	60	275	6.3
GIR	84	40	2	9	16	15	24	35	88	54	60	343	4.1
Total	—	78	34	57	44	50	48	42	88	63	60	—	—

CR (60 species)  
Region 1 = 4  
Region 6 = 4  
Region 2 = 10  
Region 7 = 2  
Region 3 = 10  
Region 8 = 8  
Region 4 = 3  
Region 9 = 7  
Region 5 = 6  
Region 10 = 6

Based on these data, the mean regional occupancy value for the CR is 5.4 (321/60). The mean regional occupancy values for the 10 regions range from 4.1 to 6.9 (Table 6), as follows (in numerical order):

GIR = 4.1  
VR = 6.2  
LCVR = 5.0  
PIR = 6.3  
BCCFR = 5.2  
CGCR = 6.4  
CR = 5.4  
SLLR = 6.4  
ATR = 5.8  
MR = 6.9

The regional occupancy values roughly indicate the relative conservation significance of each of the 10 regions. Thus, the GIR evidently is the most conservation significant region in the Baja California Peninsula, and the MR is the least. Thus, even though the GIR is the region with the highest herpetofaunal figure (84), it supports the highest degree of single-region species, the peninsular endemic species.

As in other MCS studies, we constructed a Coefficient of Biogeographic Resemblance (CBR) matrix in order to elucidate the similarity relationships among the 10 phytogeographic regions we recognize in the Baja

California Peninsula, including its associated islands on both the Pacific and Gulf sides (Table 7). The greatest species richness is contained in the Gulf Island Region (84 species), and the least is in the Baja California Coniferous Forest Region (27 species). The number of shared species between each regional pair ranges from eight between the BCCFR (27 species) and SLLR (41 species), which are relatively small areas located roughly at opposite ends of the peninsula and contain relatively small numbers of species, to 54 between the CGCR (62 species) and ATR (65 species), which are relatively low-elevation regions containing relatively high species numbers and are contiguous in the Cape Region of the peninsula. The mean value of shared species among all 10 regions is 29.9.

The following data show the ranges and means of shared species (bold in parentheses) for each of the 10 regions, and are arranged according to decreasing species richness (underlined values) in each region:

GIR (84): 9–41 (**30.3**)  
LCVR (67): 15–43 (**30.4**)  
ATR (65): 10–54 (**35.4**)  
VR (64): 16–48 (**37.1**)  
CGCR (62): 11–54 (**37.3**)  
CR (60): 18–45 (**29.3**)  
MR (51): 11–48 (**34.1**)  
PIR (47): 13–33 (**27.4**)  
SLLR (41): 8–39 (**24.9**)  
BCCFR (27): 8–23 (**12.9**)

The lowest number of shared species in Table 7, i.e., eight between the BCCFR and the SLLR, is understandable inasmuch as six species occur in all 10 of the phytogeographic regions. These six species are *Uta stansburiana*, *Lampropeltis californiae*, *Masticophis fuliginosus*, *Salvadora hexalepis*, *Hypsiglena ochrorhynchus*, and *Crotalus ruber* (Table 4). The other two species that occur in nine regions are *Pseudacris hypochondriaca* and *Trimorphodon lyrophanes*.

**Table 7.** Pair-wise comparison matrix of Coefficient of Biogeographic Resemblance (CBR) data of the herpetofaunal relationships for the 10 physiographic regions in the Baja California Peninsula, Mexico. Underlined values = number of species in each region; upper triangular matrix values = species in common between two regions; and lower triangular matrix values = CBR values. The formula for this algorithm is:  $CBR = 2C/N_1 + N_2$  (Duellman 1990), where C is the number of species in common to both regions,  $N_1$  is the number of species in the first region, and  $N_2$  is the number of species in the second region. See Table 4 for abbreviations. See Fig. 24 for the UPGMA dendrogram produced from the CBR data.

	CR	LCVR	BCCFR	VR	CGCR	MR	ATR	SLLR	PIR	GIR
CR	<u>60</u>	36	23	45	31	28	26	18	33	24
LCVR	0.56	<u>68</u>	15	43	37	33	31	20	27	32
BCCFR	0.53	0.32	<u>27</u>	16	11	11	10	8	13	9
VR	0.73	0.65	0.35	<u>64</u>	48	45	42	27	33	35
CGCR	0.51	0.57	0.25	0.76	<u>62</u>	48	54	36	32	39
MR	0.50	0.53	0.28	0.78	0.85	<u>51</u>	46	28	31	37
ATR	0.42	0.32	0.22	0.66	0.86	0.80	<u>65</u>	39	30	41
SLLR	0.36	0.37	0.24	0.51	0.70	0.61	0.74	<u>41</u>	20	28
PIR	0.62	0.47	0.35	0.59	0.59	0.63	0.54	0.45	<u>47</u>	28
GIR	0.33	0.42	0.16	0.47	0.53	0.55	0.55	0.45	0.43	<u>84</u>

Interestingly and perhaps expectedly, only one of the eight is an amphibian, one is a lizard, and the remaining six are snakes.

In addition, the two insular regions positioned on either side of the peninsula (PIR and GIR) might be expected to share relatively few species. Their number of shared species (28) is higher than the number between the BCCFR and the SLLR (Table 7). These 28 species include the six occurring in all 10 regions, as well as one in four regions, two in five regions, one in six regions, three in seven regions, 10 in eight regions, and five in nine regions. Notably, no insular endemic species are shared between these two insular regions. The six peninsular endemic species found in these two insular regions also are found on the intervening mainland regions, and in total are found in five to nine regions.

The CBR values in Table 6 range from 0.16 between the BCCFR and the GIR to 0.86 between the ATR and the CGCR. These relationships easily are understood given that the BCCFR is a “cool mesic area” occupying the “upper elevations of the northern Sierra Juárez and southern Sierra San Pedro Mártir...” (Grismer, 2002: 12) and the GIR is comprised of the islands in the Gulf region. In addition, the ATR and the CGCR are two regions in the southern portion of the peninsula that are broadly contiguous and overlapping.

### UPGMA dendrogram

The UPGMA dendrogram (Fig. 24) indicates that the two most closely related regions are the adjacent and overlapping Central Gulf Coast Region (CGCR) and the Arid Tropical Region (ATR), which are joined at the 0.86 level. These two regions are joined at the 0.82 level with the Magdalena Region (MR), which is adjacent with both of the Central Gulf Coast and Arid Tropical Regions for some distance. These three regions are joined at the 0.74 level with the Vizcaíno Region (VR), which is adjacent

to both the Central Gulf Coast and Magdalena Regions. These four regions are joined at the 0.64 level with the Sierra La Laguna Region (SLLR), which is located in the southern cape region of Baja California Sur and surrounded by the Arid Tropical Region. This group of five regions in the southern portion of the Peninsula is joined to the remaining regions in the northern portion of the Peninsula and those in the Pacific Ocean and the Gulf of California at the 0.52 level. Of the remaining five regions, the regions most closely allied are the Pacific Islands Region and the California Region, joined at the 0.62 level. These two regions are united to the other three regions at the 0.51 level with the Lower Colorado Valley Region (LCVR). The eight previously mentioned peninsular regions are joined to the Gulf Islands Region at the 0.44 level. Finally, and notably, the most distantly related region is the Baja California Coniferous Forest Region, which is joined to all the other regions at the 0.33 level and is “the southernmost disjunct and depauperate section of the broader and more inclusive Sierra Montane Conifer Forest” (Grismer 2002: 11–12). This region has the smallest herpetofauna (27 species) of the 10 regions, and the lowest average number of species in common (12.9) with the remaining regions (see above and Table 7).

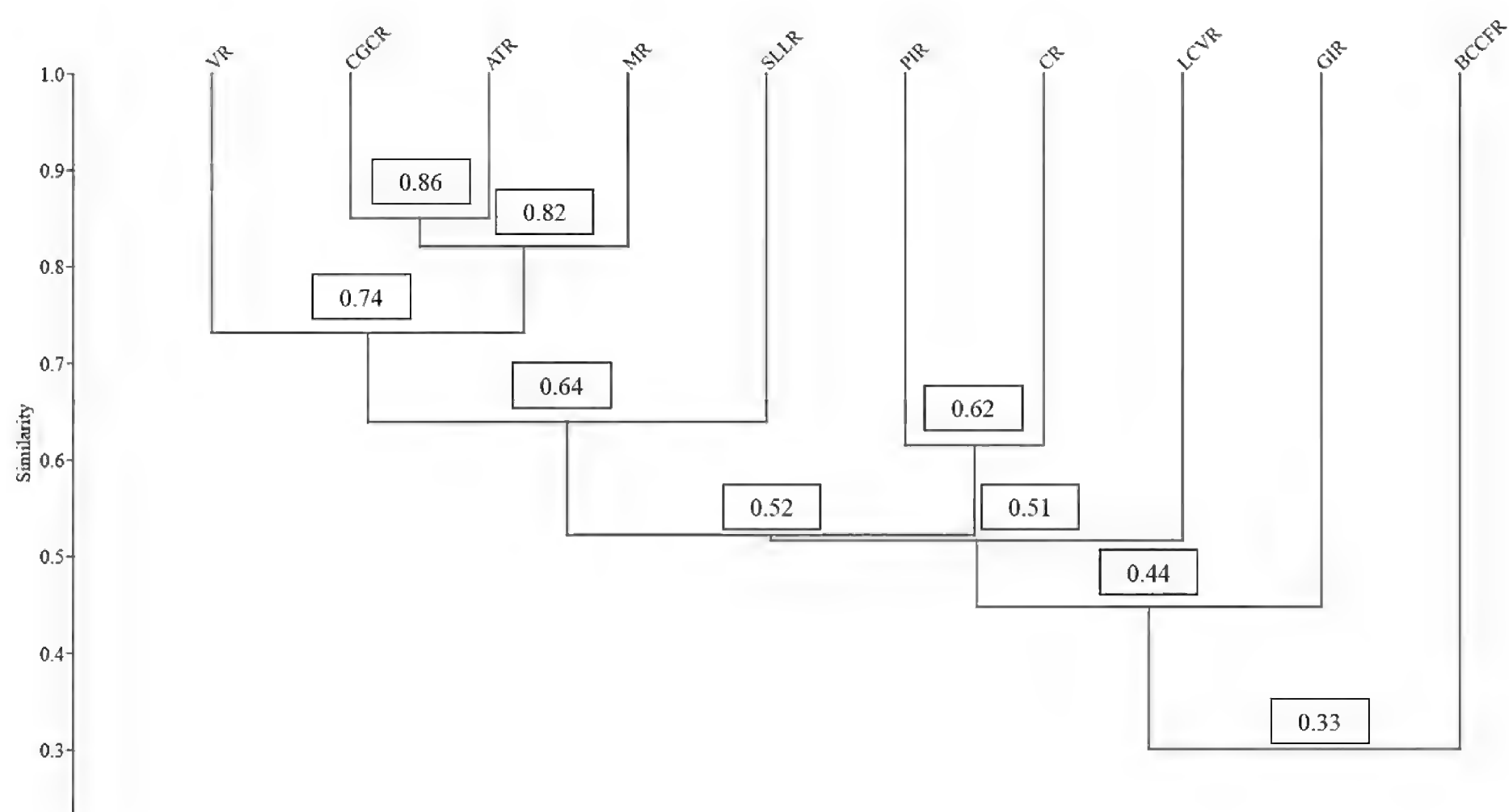
### Distribution Status Categorizations

We used the system developed by Alvarado-Díaz et al. (2013) to discuss the distribution status of the members of the Baja California herpetofauna, as was used in the previous studies in the MCS (see above). The categories in this system have been somewhat adapted to include the following: non-endemic, peninsular endemic, and non-native. The categorizations for each species are listed in Table 8, and summarized in Table 9.

The species numbers in each of the three distribution categories, in decreasing order, are: non-endemics, 81 (47.1%); peninsular endemics, 77 (44.8%); and non-



The herpetofauna of the Baja California Peninsula



**Fig. 24.** UPGMA generated dendrogram illustrating the similarity relationships of species richness among the herpetofaunal components in the 10 geographic regions of the Baja California Peninsula (based on the data in Table 6; Sokal and Michener 1958). Similarity values were calculated using Duellman’s (1990) Coefficient of Biogeographic Resemblance (CBR).

natives, 14 (8.1%). These distribution categories differ from those utilized in other MCS studies, inasmuch as the Baja California Peninsula is almost completely segmented from the remainder of the country of Mexico, and biogeographically it is much more closely associated with the US state of California (Mata-Silva et al., In Press). Therefore, it is not possible to separate country endemics from state endemics, as was done in the other MCS studies, but rather they are recognized here as only a single category, i.e., the peninsular endemic category (Table 7).

As expected, almost all of the non-endemic species (74, or 91.4% from a total of 81 species) are categorized as NE3 or MXUS species (i.e., species occurring in both Mexico and the United States), according to the categories established by Wilson et al. (2017). However, one species (1.2%) is an NE7 or USCA species (*Thamnophis marcianus*), i.e., a species occurring from the United States to Central America; and six (7.4%) are NE9 or OCEA species (one marine snake, *Hydrophis platurus*, and five marine turtles, *Caretta caretta*, *Chelonia mydas*, *Eretmochelys imbricata*, *Lepidochelys olivacea*, and *Dermochelys coriacea*).

The peninsular endemic species amount to 77 and occupy from one to nine geographic regions (Table 7): one region (46 species, 60.5%); two (four, 5.3%); three (eight, 10.5%); four (five, 6.6%); five (eight, 10.5%); six (none); seven (two, 2.6%); eight (three, 3.9%); and nine (one, 1.3%). The 46 species confined to a single geographic region are either mostly limited to the Pacific Insular Region (four species) or the Gulf Insular Region (38 species). The following four species are confined to the Pacific Insular Region:

- Elgaria cedrosensis*\*\*
- Elgaria nana*\*\*
- Lampropeltis herrerae*\*\*
- Pituophis insulanus*\*\*

The 38 species limited to the Gulf Insular Region are:

- Crotaphytus insularis*\*\*
- Coleonyx gypsicolus*\*\*
- Dipsosaurus catalinensis*\*\*
- Sauromalus hispidus*\*\*
- Sauromalus klauberi*\*\*
- Sauromalus slevini*\*\*
- Petrosaurus slevini*\*\*
- Sceloporus angustus*\*\*
- Sceloporus grandaevus*\*\*
- Sceloporus lineatulus*\*\*
- Uta encantadae*\*\*
- Uta lowei*\*\*
- Uta squamata*\*\*
- Uta tumidarostra*\*\*
- Phyllodactylus bugastrolepis*\*\*
- Phyllodactylus partidus*\*\*
- Aspidoscelis canus*\*\*
- Aspidoscelis carmenensis*\*\*
- Aspidoscelis catalinensis*\*\*
- Aspidoscelis celeripes*\*\*
- Aspidoscelis ceralbensis*\*\*
- Aspidoscelis danheimae*\*\*
- Aspidoscelis espiritensis*\*\*
- Aspidoscelis franciscensis*\*\*
- Aspidoscelis pictus*\*\*

**Table 8.** Distributional and conservation status measures for members of the herpetofauna of the Baja California Peninsula, Mexico. Distributional status: PE = endemic to Peninsula of Baja California; NE = not endemic to peninsula; and NN = non-native. The numbers suffixed to the NE category signify the distributional categories developed by Wilson et al. (2017) and implemented in the taxonomic list at the *Mesoamerican Herpetology* website (<http://mesoamericanherpetology.com>), as follows: 3 (species distributed only in Mexico and the United States); 4 (species found only in Mexico and Central America); 6 (species ranging from Mexico to South America); 7 (species ranging from the United States to Central America); 8 (species ranging from the United States to South America); and 9 (Oceanic species). Environmental Vulnerability Score (taken from Wilson et al. 2013a,b): low (L) vulnerability species (EVS of 3–9); medium (M) vulnerability species (EVS of 10–13); and high (H) vulnerability species (EVS of 14–19). IUCN categorization: CR = Critically Endangered; EN = Endangered; VU = Vulnerable; NT = Near Threatened; LC = Least Concern; DD = Data Deficient; and NE = Not Evaluated. SEMARNAT status: A = Threatened; P = Endangered; Pr = Special Protection; and NS = No Status. See Alvarado-Díaz et al. (2013), Johnson et al. (2015a), and Mata-Silva et al. (2015) for explanations of the EVS, IUCN, and SEMARNAT rating systems.

Taxon	Distributional status	Environmental Vulnerability Category (Score)	IUCN categorization	SEMARNAT status
<i>Anaxyrus boreas</i>	NE3	L (7)	LC	NS
<i>Anaxyrus californicus</i>	NE3	M (11)	EN	A
<i>Anaxyrus cognatus</i>	NE3	L (4)	LC	NS
<i>Anaxyrus punctatus</i>	NE3	L (3)	LC	NS
<i>Anaxyrus woodhousii</i>	NE3	M (10)	LC	NS
<i>Incilius alvarius</i>	NE3	M (11)	LC	NS
<i>Pseudacris cadaverina</i>	NE3	M (11)	LC	NS
<i>Pseudacris hypochondriaca</i>	NE3	L (9)	LC	NS
<i>Smilisca baudinii</i> ***	NN	—	—	—
<i>Xenopus laevis</i> ***	NN	—	—	—
<i>Lithobates berlandieri</i> ***	NN	—	—	—
<i>Lithobates catesbeianus</i> ***	NN	—	—	—
<i>Lithobates forreri</i> ***	NN	—	—	—
<i>Lithobates yavapaiensis</i>	NE3	M (12)	LC	Pr
<i>Rana boylei</i>	NE3	M (12)	NT	Pr
<i>Rana draytonii</i>	NE3	M (11)	NT	P
<i>Scaphiopus couchii</i>	NE3	L (3)	LC	NS
<i>Spea hammondi</i>	NE3	M (11)	NT	NS
<i>Aneides lugubris</i>	NE3	H (14)	LC	Pr
<i>Batrachoseps major</i>	NE3	H (14)	LC	NS
<i>Ensatina eschscholtzii</i>	NE3	M (13)	LC	Pr
<i>Elgaria cedrosensis</i> **	PE	H (16)	LC	NS
<i>Elgaria multicarinata</i>	NE3	M (10)	LC	Pr
<i>Elgaria nana</i> **	PE	H (16)	LC	NS
<i>Elgaria paucicarinata</i> **	PE	H (14)	LC	Pr
<i>Elgaria velazquezii</i> **	PE	H (15)	LC	NS
<i>Anniella geronimensis</i> **	PE	H (14)	EN	Pr
<i>Anniella stebbinsi</i>	NE3	M (11)	NE	Pr
<i>Bipes biporus</i> **	PE	H (19)	LC	Pr
<i>Crotaphytus grismeri</i> **	PE	H (16)	LC	NS
<i>Crotaphytus insularis</i> **	PE	H (16)	LC	NS
<i>Crotaphytus vestigium</i>	NE3	L (9)	LC	NS
<i>Gambelia copeii</i> **	NE3	M (11)	LC	NS
<i>Gambelia wislizenii</i>	NE3	M (12)	LC	Pr
<i>Coleonyx gypsicolus</i> **	PE	H (16)	LC	NS
<i>Coleonyx switaki</i>	NE3	H (10)	LC	NS
<i>Coleonyx variegatus</i>	NE3	M (9)	LC	Pr
<i>Gehyra mutilata</i> ***	NN	—	—	—
<i>Hemidactylus frenatus</i> ***	NN	—	—	—
<i>Hemidactylus turcicus</i> ***	NN	—	—	—
<i>Ctenosaura hemilopha</i> **	PE	H (16)	LC	Pr
<i>Dipsosaurus catalinensis</i> **	PE	H (17)	NE	NS
<i>Dipsosaurus dorsalis</i>	NE3	M (12)	LC	NS

## The herpetofauna of the Baja California Peninsula

**Table 8 (continued).** Distributional and conservation status measures for members of the herpetofauna of the Baja California Peninsula, Mexico. Distributional status: PE = endemic to Peninsula of Baja California; NE = not endemic to peninsula; and NN = non-native. The numbers suffixed to the NE category signify the distributional categories developed by Wilson et al. (2017) and implemented in the taxonomic list at the *Mesoamerican Herpetology* website (<http://mesoamericanherpetology.com>), as follows: 3 (species distributed only in Mexico and the United States); 4 (species found only in Mexico and Central America); 6 (species ranging from Mexico to South America); 7 (species ranging from the United States to Central America); 8 (species ranging from the United States to South America); and 9 (Oceanic species). Environmental Vulnerability Score (taken from Wilson et al. 2013a,b): low (L) vulnerability species (EVS of 3–9); medium (M) vulnerability species (EVS of 10–13); and high (H) vulnerability species (EVS of 14–19). IUCN categorization: CR = Critically Endangered; EN = Endangered; VU = Vulnerable; NT = Near Threatened; LC = Least Concern; DD = Data Deficient; and NE = Not Evaluated. SEMARNAT status: A = Threatened; P = Endangered; Pr = Special Protection; and NS = No Status. See Alvarado-Díaz et al. (2013), Johnson et al. (2015a), and Mata-Silva et al. (2015) for explanations of the EVS, IUCN, and SEMARNAT rating systems.

Taxon	Distributional status	Environmental Vulnerability Category (Score)	IUCN categorization	SEMARNAT status
<i>Iguana rhinolopha</i> ***	NN	—	—	—
<i>Sauromalus ater</i>	NE3	M (13)	LC	Pr
<i>Sauromalus hispidus</i> **	PE	H (14)	EN	A
<i>Sauromalus klauberi</i> **	PE	H (17)	VU	A
<i>Sauromalus slevini</i> **	PE	H (16)	NT	A
<i>Sauromalus varius</i> ***	NN	—	—	—
<i>Callisaurus draconoides</i>	NE3	M (12)	LC	A
<i>Petrosaurus mearnsi</i>	NE3	M (10)	LC	Pr
<i>Petrosaurus repens</i> **	PE	H (14)	LC	NS
<i>Petrosaurus slevini</i> **	PE	H (16)	LC	NS
<i>Petrosaurus thalassinus</i> **	PE	H (17)	LC	Pr
<i>Phrynosoma blainvillii</i>	NE3	M (12)	LC	NS
<i>Phrynosoma cerroense</i> **	PE	H (14)	NE	A
<i>Phrynosoma coronatum</i> **	PE	M (12)	LC	NS
<i>Phrynosoma mcallii</i>	NE3	H (15)	NT	A
<i>Phrynosoma platyrhinos</i>	NE3	M (13)	LC	NS
<i>Sceloporus angustus</i> **	PE	H (16)	LC	A
<i>Sceloporus grandaevus</i> **	PE	H (17)	LC	A
<i>Sceloporus hunsakeri</i> **	PE	H (14)	LC	Pr
<i>Sceloporus licki</i> **	PE	M (13)	LC	Pr
<i>Sceloporus lineatulus</i> **	PE	H (17)	LC	A
<i>Sceloporus magister</i>	NE3	L (9)	LC	NS
<i>Sceloporus occidentalis</i>	NE3	M (11)	LC	NS
<i>Sceloporus orcutti</i>	NE3	L (7)	LC	NS
<i>Sceloporus vandenburgianus</i>	NE3	H (14)	LC	Pr
<i>Sceloporus zosteromus</i> **	PE	M (12)	LC	Pr
<i>Uma notata</i>	NE3	H (15)	NT	P
<i>Urosaurus graciosus</i>	NE3	H (15)	LC	NS
<i>Urosaurus lahtelai</i> **	PE	H (16)	LC	A
<i>Urosaurus nigricaudus</i>	NE3	L (7)	LC	A
<i>Urosaurus ornatus</i>	NE3	L (9)	LC	NS
<i>Uta encantadae</i> **	PE	H (17)	VU	NS
<i>Uta lowei</i> **	PE	H (17)	VU	NS
<i>Uta squamata</i> **	PE	H (17)	LC	A
<i>Uta stansburiana</i>	NE3	L (5)	LC	A
<i>Uta tumidarostra</i> **	PE	H (17)	VU	NS
<i>Phyllodactylus bugastrolepis</i> **	PE	H (17)	LC	A
<i>Phyllodactylus nocticolus</i>	NE3	M (10)	LC	Pr
<i>Phyllodactylus partidus</i> **	PE	H (16)	LC	Pr
<i>Phyllodactylus unctus</i> **	PE	H (15)	NT	Pr
<i>Phyllodactylus xanti</i> **	PE	H (15)	LC	Pr
<i>Plestiodon gilberti</i>	NE3	M (11)	LC	Pr
<i>Plestiodon lagunensis</i> **	PE	M (13)	LC	Pr



**Table 8 (continued).** Distributional and conservation status measures for members of the herpetofauna of the Baja California Peninsula, Mexico. Distributional status: PE = endemic to Peninsula of Baja California; NE = not endemic to peninsula; and NN = non-native. The numbers suffixed to the NE category signify the distributional categories developed by Wilson et al. (2017) and implemented in the taxonomic list at the *Mesoamerican Herpetology* website (<http://mesoamericanherpetology.com>), as follows: 3 (species distributed only in Mexico and the United States); 4 (species found only in Mexico and Central America); 6 (species ranging from Mexico to South America); 7 (species ranging from the United States to Central America); 8 (species ranging from the United States to South America); and 9 (Oceanic species). Environmental Vulnerability Score (taken from Wilson et al. 2013a,b): low (L) vulnerability species (EVS of 3–9); medium (M) vulnerability species (EVS of 10–13); and high (H) vulnerability species (EVS of 14–19). IUCN categorization: CR = Critically Endangered; EN = Endangered; VU = Vulnerable; NT = Near Threatened; LC = Least Concern; DD = Data Deficient; and NE = Not Evaluated. SEMARNAT status: A = Threatened; P = Endangered; Pr = Special Protection; and NS = No Status. See Alvarado-Díaz et al. (2013), Johnson et al. (2015a), and Mata-Silva et al. (2015) for explanations of the EVS, IUCN, and SEMARNAT rating systems.

Taxon	Distributional status	Environmental Vulnerability Category (Score)	IUCN categorization	SEMARNAT status
<i>Plestiodon skiltonianus</i>	NE3	M (10)	LC	NS
<i>Aspidoscelis camus</i> **	PE	H (17)	LC	A
<i>Aspidoscelis carmenensis</i> **	PE	H (17)	LC	NS
<i>Aspidoscelis catalinensis</i> **	PE	H (17)	VU	Pr
<i>Aspidoscelis celeripes</i> **	PE	H (16)	LC	Pr
<i>Aspidoscelis ceralbensis</i> **	PE	H (17)	LC	Pr
<i>Aspidoscelis danheimae</i> **	PE	H (17)	LC	A
<i>Aspidoscelis espiritensis</i> **	PE	H (16)	LC	A
<i>Aspidoscelis franciscensis</i> **	PE	H (17)	LC	NS
<i>Aspidoscelis hyperythrus</i>	NE3	M (10)	LC	NS
<i>Aspidoscelis labialis</i> **	PE	H (15)	VU	Pr
<i>Aspidoscelis maximus</i> **	PE	H (14)	NE	Pr
<i>Aspidoscelis pictus</i> **	PE	H (17)	LC	A
<i>Aspidoscelis tigris</i>	NE3	L (8)	LC	NS
<i>Xantusia gilberti</i> **	PE	H (15)	NE	NS
<i>Xantusia henshawi</i>	NE3	M (11)	LC	NS
<i>Xantusia sherbrookei</i> **	PE	H (15)	NE	NS
<i>Xantusia wigginsi</i>	NE3	M (11)	NE	NS
<i>Lichanura trivirgata</i>	NE3	M (10)	LC	A
<i>Arizona elegans</i>	NE3	L (5)	LC	NS
<i>Arizona pacata</i> **	PE	H (14)	LC	NS
<i>Bogertophis rosaliae</i>	NE3	M (11)	LC	NS
<i>Lampropeltis californiae</i>	NE3	L (9)	LC	A
<i>Lampropeltis catalinensis</i> **	PE	H (18)	DD	NS
<i>Lampropeltis herrerae</i> **	PE	H (20)	LC	A
<i>Lampropeltis multifasciata</i>	NE3	H (14)	NE	A
<i>Masticophis aurigulus</i> **	PE	H (15)	LC	A
<i>Masticophis barbouri</i> **	PE	H (17)	DD	A
<i>Masticophis flagellum</i>	NE3	L (8)	LC	A
<i>Masticophis fuliginosus</i>	NE3	L (9)	NE	NS
<i>Masticophis lateralis</i>	NE3	M (12)	LC	NS
<i>Phyllorhynchus decurtatus</i>	NE3	M (12)	LC	NS
<i>Pituophis catenifer</i>	NE3	L (7)	LC	NS
<i>Pituophis insulanus</i> **	PE	H (17)	LC	NS
<i>Pituophis vertebralis</i> **	PE	M (13)	LC	NS
<i>Rhinocheilus etheridgei</i> **	PE	H (17)	DD	A
<i>Rhinocheilus lecontei</i>	NE3	L (8)	LC	NS
<i>Salvadora hexalepis</i>	NE3	L (9)	LC	NS
<i>Sonora annulata</i>	NE3	H (14)	NE	NS
<i>Sonora cincta</i> **	NE3	L (8)	NE	Pr
<i>Sonora fasciata</i> **	PE	M (12)	NE	Pr
<i>Sonora mosaueri</i> **	PE	M (12)	NE	NS
<i>Sonora punctatissima</i> **	PE	H (15)	NE	Pr

## The herpetofauna of the Baja California Peninsula

**Table 8 (continued).** Distributional and conservation status measures for members of the herpetofauna of the Baja California Peninsula, Mexico. Distributional status: PE = endemic to Peninsula of Baja California; NE = not endemic to peninsula; and NN = non-native. The numbers suffixed to the NE category signify the distributional categories developed by Wilson et al. (2017) and implemented in the taxonomic list at the *Mesoamerican Herpetology* website (<http://mesoamericanherpetology.com>), as follows: 3 (species distributed only in Mexico and the United States); 4 (species found only in Mexico and Central America); 6 (species ranging from Mexico to South America); 7 (species ranging from the United States to Central America); 8 (species ranging from the United States to South America); and 9 (Oceanic species). Environmental Vulnerability Score (taken from Wilson et al. 2013a,b): low (L) vulnerability species (EVS of 3–9); medium (M) vulnerability species (EVS of 10–13); and high (H) vulnerability species (EVS of 14–19). IUCN categorization: CR = Critically Endangered; EN = Endangered; VU = Vulnerable; NT = Near Threatened; LC = Least Concern; DD = Data Deficient; and NE = Not Evaluated. SEMARNAT status: A = Threatened; P = Endangered; Pr = Special Protection; and NS = No Status. See Alvarado-Díaz et al. (2013), Johnson et al. (2015a), and Mata-Silva et al. (2015) for explanations of the EVS, IUCN, and SEMARNAT rating systems.

Taxon	Distributional status	Environmental Vulnerability Category (Score)	IUCN categorization	SEMARNAT status
<i>Sonora savagei</i> **	PE	H (16)	LC	Pr
<i>Sonora straminea</i> **	PE	H (15)	NE	Pr
<i>Sonora semiannulata</i>	NE3	L (6)	LC	NS
<i>Tantilla planiceps</i>	NE3	L (8)	LC	NS
<i>Trimorphodon lyrophanes</i>	NE3	M (11)	LC	NS
<i>Diadophis punctatus</i>	NE3	L (4)	LC	NS
<i>Hypsiglena catalinae</i> **	NN	H (16)	NE	Pr
<i>Hypsiglena chlorophaea</i>	NE3	M (10)	LC	NS
<i>Hypsiglena gularis</i> **	PE	H (16)	LC	NS
<i>Hypsiglena marcosensis</i> **	PE	H (16)	NE	NS
<i>Hypsiglena ochrorhynchus</i>	NE3	M (10)	NE	Pr
<i>Hypsiglena slevini</i> **	PE	M (11)	LC	NS
<i>Hydrophis platurus</i>	NE9	—	LC	NS
<i>Rena boettgeri</i> **	PE	H (14)	NE	NS
<i>Rena humilis</i>	NE3	L (8)	LC	NS
<i>Thamnophis elegans</i>	NE3	H (14)	LC	A
<i>Thamnophis hammondi</i>	NE3	M (12)	LC	A
<i>Thamnophis marcianus</i>	NE7	L (9)	LC	A
<i>Thamnophis validus</i> **	PE	M (11)	LC	NS
<i>Indotyphlops braminus</i> ***	NN	—	—	—
<i>Crotalus angelensis</i> **	PE	H (18)	LC	NS
<i>Crotalus atrox</i>	NE3	L (9)	LC	Pr
<i>Crotalus catalinensis</i> **	PE	H (19)	CR	A
<i>Crotalus cerastes</i>	NE3	H (16)	LC	Pr
<i>Crotalus enyo</i> **	PE	M (13)	LC	A
<i>Crotalus helleri</i>	NE3	M (12)	NE	Pr
<i>Crotalus lorenzoensis</i> **	PE	H (19)	LC	NS
<i>Crotalus mitchellii</i> **	PE	H (15)	LC	Pr
<i>Crotalus polisi</i> **	PE	H (19)	NE	Pr
<i>Crotalus pyrrhus</i>	NE3	M (13)	NE	Pr
<i>Crotalus ruber</i>	NE3	L (9)	LC	Pr
<i>Crotalus thalassoporus</i> **	PE	H (19)	NE	Pr
<i>Caretta caretta</i>	NE9	—	LC	P
<i>Chelonia mydas</i>	NE9	—	EN	P
<i>Eretmochelys imbricata</i>	NE9	—	CR	P
<i>Lepidochelys olivacea</i>	NE9	—	VU	P
<i>Dermochelys coriacea</i>	NE9	—	CR	P
<i>Actinemys pallida</i>	NE3	M (13)	VU	NS
<i>Trachemys nebulosa</i> **	PE	H (15)	NE	NS
<i>Trachemys scripta</i> ***	NN	—	—	—
<i>Kinosternon integrum</i> ***	NN	—	—	—
<i>Gopherus morafkai</i>	NE3	H (15)	NE	A
<i>Apalone spinifera</i> ***	NN	—	—	—

**Table 9.** Summary of the distributional status data for the herpetofaunal families in the Baja California Peninsula, Mexico.

Family	Number of species	Distributional status		
		Non-endemic (NE)	Peninsular Endemic (CE)	Non-native (NN)
Bufonidae	6	6	—	—
Hylidae	3	2	—	1
Pipidae	1	—	—	1
Ranidae	6	3	—	3
Scaphiopodidae	2	2	—	—
<b>Subtotal</b>	<b>18</b>	<b>13</b>	<b>—</b>	<b>5</b>
Plethodontidae	3	3	—	—
<b>Subtotal</b>	<b>3</b>	<b>3</b>	<b>—</b>	<b>—</b>
<b>Total</b>	<b>21</b>	<b>16</b>	<b>—</b>	<b>5</b>
Anguidae	5	1	4	—
Anniellidae	2	1	1	—
Bipedidae	1	—	1	—
Crotaphytidae	5	2	3	—
Eublepharidae	3	2	1	—
Gekkonidae	3	—	—	3
Iguanidae	9	2	5	2
Phrynosomatidae	30	14	16	—
Phyllodactylidae	5	1	4	—
Scincidae	3	2	1	—
Teiidae	13	2	11	—
Xantusiidae	4	2	2	—
<b>Subtotal</b>	<b>83</b>	<b>29</b>	<b>49</b>	<b>5</b>
Boidae	1	1	—	—
Colubridae	29	15	14	—
Dipsadidae	7	3	4	—
Elapidae	1	1	—	—
Leptotyphlopidae	2	1	1	—
Natricidae	4	3	1	—
Typhlopidae	1	—	—	1
Viperidae	12	5	7	—
<b>Subtotal</b>	<b>57</b>	<b>29</b>	<b>27</b>	<b>1</b>
Cheloniidae	4	4	—	—
Dermochelyidae	1	1	—	—
Emydidae	3	1	1	1
Kinosternidae	1	—	—	1
Testudinidae	1	1	—	—
Trionychidae	1	—	—	1
<b>Subtotal</b>	<b>11</b>	<b>7</b>	<b>1</b>	<b>3</b>
<b>Total</b>	<b>151</b>	<b>65</b>	<b>77</b>	<b>9</b>
<b>Sum total</b>	<b>172</b>	<b>81</b>	<b>77</b>	<b>14</b>

*Lampropeltis catalinensis*\*\*  
*Masticophis barbouri*\*\*  
*Rhinocheilus etheridgei*\*\*  
*Sonora punctatissima*\*\*  
*Sonora savagei*\*\*  
*Hypsiglena catalinae*\*\*  
*Hypsiglena gularis*\*\*  
*Hypsiglena marcosensis*\*\*  
*Crotalus angelensis*\*\*  
*Crotalus catalinensis*\*\*  
*Crotalus lorenzoensis*\*\*

*Crotalus polisi*\*\*  
*Crotalus thalassoporus*\*\*

The 14 non-native species include five anurans (*Smilisca baudinii*, *Xenopus laevis*, *Lithobates berlandieri*, *L. catesbeianus*, and *L. forreri*), five lizards (*Gehyra mutilata*, *Hemidactylus frenatus*, *H. turcicus*, *Iguana rhinolopha*, and *Sauromalus varius*), one snake (*Indotyphlops braminus*), and three turtles (*Trachemys scripta*, *Kinosternon integrum*, and *Apalone spinifera*). The most widespread of these introduced species in



Mexico are *Hemidactylus frenatus* and *Indotyphlops braminus* (González-Sánchez et al. 2021), and the most widely distributed of these species in the Baja California peninsula is *Hemidactylus frenatus* (Table 4).

## Principal Environmental Threats

The main threat to the planet's biodiversity is the combination of human population growth and the exploitation of natural resources. The human population requires resources to survive and grow, and these resources often are removed from the environment in unsustainable ways. This problem becomes larger as the human population grows. As threats to biodiversity are occurring worldwide, Mexico also is subject to many of these threats (Santos-Barrera et al. 2021), and the Baja California Peninsula is no exception. In this section we highlight the most significant problems we believe are affecting the conservation of amphibian and reptile populations in the Baja California Peninsula.

**Land conversion and habitat loss.** In general, this threat is the major reason for biodiversity loss (Leclère et al. 2020; Bellard et al. 2022), and specifically for amphibians and reptiles (Wake 1991; Gibbons et al. 2000; Böhm et al. 2013). In the Baja California Peninsula, a large part of this threat occurs mainly in coastal areas where the vegetation has been cleared, and the habitat has been lost as a result of tourism and

housing development. For example, *Aspidoscelis tigris* and *Dipsosaurus dorsalis* were affected by habitat loss in the coastal sand dunes of San Felipe (Gatica-Colima 1998). This activity is more common in the Gulf of California due to the attractiveness of its beaches. Many of these mega-developments involve the clearing of large sections of natural land for the construction of buildings, golf courses, and marinas, which alter both the terrestrial and marine habitats, as well as coastal dunes and riparian areas (Rodríguez-Revelo et al. 2014b).

In other regions, the expansion of agricultural areas also affects a large part of the habitats of many species throughout the peninsula (Fig. 25). Most of these crops are monocultures that serve as an ecological trap for organisms inhabiting nearby natural semiarid habitats (Rotem et al. 2013). One of the areas most affected by this activity is the Santo Domingo Valley in the Magdalena region of Baja California Sur. This area covers just over 260,000 ha and includes many isolated fragments of native vegetation that still contain native reptile species; nevertheless, extirpations have been detected, such as that of *Urosaurus nigricaudus* (Munguía-Vega et al. 2013). Perhaps this also is the case with other species of lizards and snakes in such agricultural areas as the Valley of Mexicali in northeastern Baja California, which covers about 280,000 ha. Another agricultural area with constant expansion is that between Colonet and San Quintín in northwestern Baja California, which has affected the coastal scrub vegetation and dune areas (Vanderplank



**Fig. 25.** Cleared land used for agriculture in San Quintín. This area was the habitat of *Anniella geronimensis*, and now is used by Driscoll's to grow berries for export to the USA. The Riveroll Volcano is evident in the background, which is the habitat of *Batrachoseps major* and *Ensatina schscholtzii*. Agriculture and rock/sand mining activities continue to threaten these unique populations of salamanders. Photo by Jorge H. Valdez-Villavicencio.

et al. 2014a), thereby causing a reduction in the habitat of the endemic lizard *Anniella geronimensis*, as well as other endemic species (e.g., *Aspidoscelis labialis* and *Sceloporus zosteromus*).

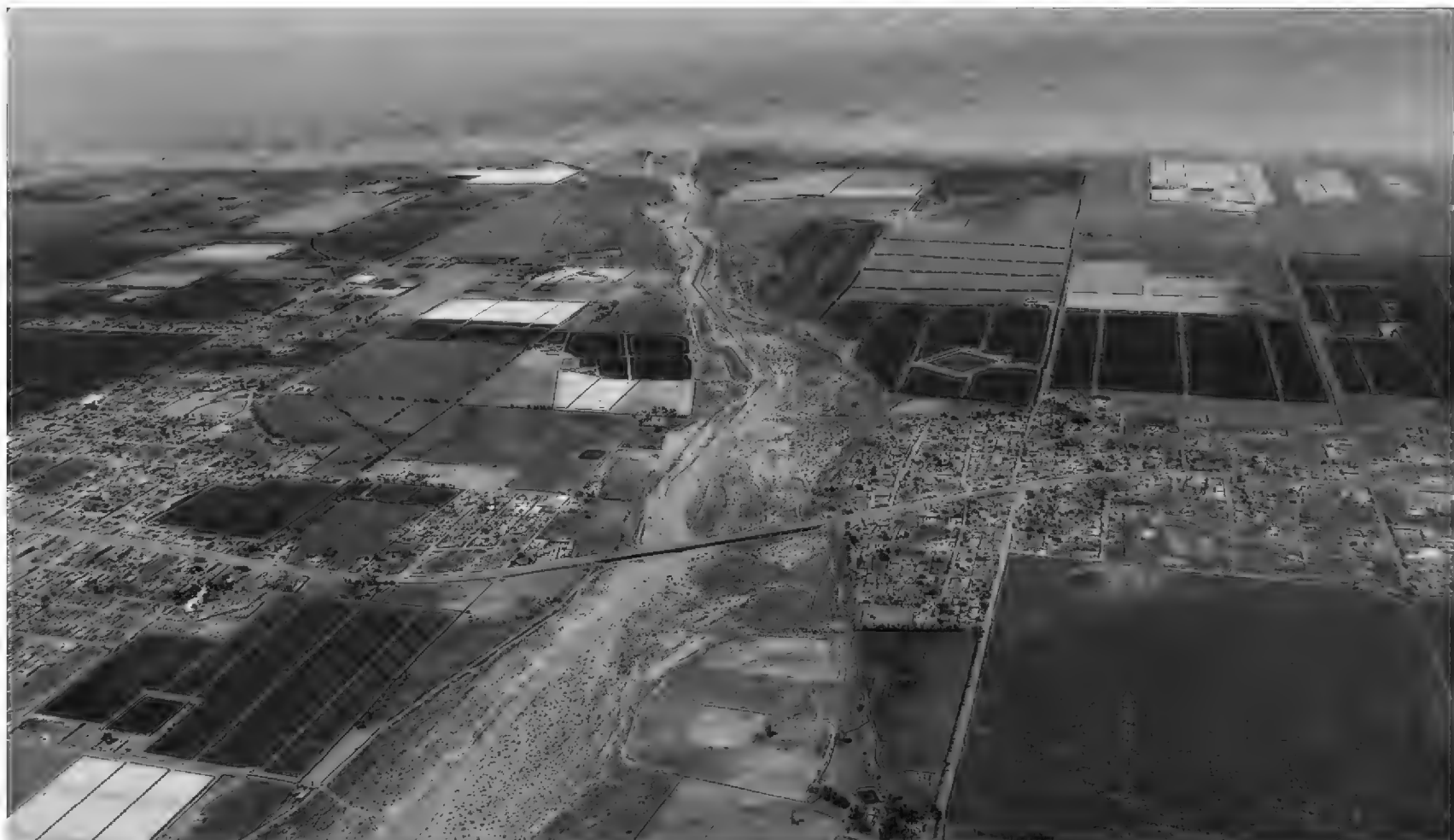
Mining concessions along the peninsula also imply the destruction of natural habitat, the excessive use of water, and habitat fragmentation due to the construction of access roads. In a short period between 2009 and 2010, 141 mining concessions were granted in the state of Baja California Sur, at least five of which are located in the Cape Region, which affected nearly 50,000 ha of habitat for many reptile species endemic to this region (Galina-Tessaro et al. 2015). Other mining activities, such as the extraction of sand from riparian areas that is used for construction and exported to the United States, have affected the habitat of the Arroyo Toad (*Anaxyrus californicus*) and the California Red-legged Frog (*Rana draytonii*) in northwestern Baja California; and both species are included in Mexico's list of threatened species (Lovich et al. 2009).

**Water diversion and overuse.** Aquatic habitats are threatened by the alteration of their physical or biotic structures based on the various ways humans use water supplies and the adjacent habitats (Figs. 26–28). The channelization of streams and excessive pumping of groundwater and surface water have the greatest effects on the aquatic habitats and their associated species (Jennings and Hayes 1994). Due to the aridity of the peninsula and the declining precipitation, evidently there is a diminution and a lack of recharge of the aquifers; therefore, the excessive use of water represents a strong threat to such freshwater species as amphibians and

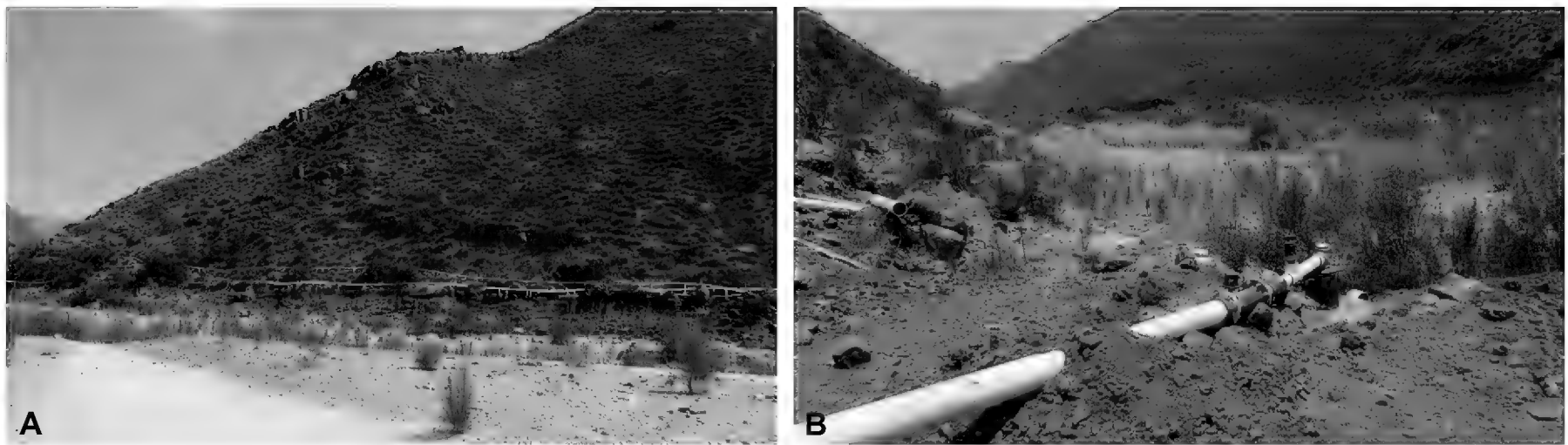
reptiles (e.g., *Thamnophis* and *Actinemys*). Notably, the extraction of water for domestic and agricultural consumption has affected the hydrology of the basins in northwestern Baja California. The excessive use of water for irrigation in agricultural areas is reducing the water levels in streams, and also causing the loss of ponds and areas with the historical presence of species such as *Anaxyrus californicus*, *Rana draytonii*, and *Actinemys pallida* (Peralta-García et al. 2016; Valdez-Villavicencio et al., In Press). In most of the watersheds the surface water no longer occurs near the coast, and in some cases it is up to 20 km inland, due to the presence of a large number of pumps used to extract the groundwater and a network of surface pipes used to distribute water throughout the agricultural region between Colonet and San Quintín.

Baja California Sur is no exception, as many of the aquifers there are overexploited, and with the scarcity of rainfall, the recharge of the aquifers is insufficient (Carrillo-Guerrero 2010; Troyo-Diéguez et al. 2010). Large amounts of water are destined for agricultural use. For example, 78% of the state's water is destined for agricultural use and 15% for public establishments such as shopping areas and hotel complexes, whose numbers keep increasing with each passing year (Graciano 2013). This situation has caused a water deficit of 54% in the state's aquifers (DOF 2020). Therefore, many of the streams and small oases no longer have the surface water which is vital for the survival of amphibians and reptiles (e.g., *Trachemys nebulosa* and *Thamnophis hammondi*).

**Invasive species.** Introduced species are considered one of the main causes of amphibian and reptile



**Fig. 26.** An aerial image of San Quintín agricultural valley, which surrounds Arroyo Santo Domingo. A large patch of wetland was present at the mouth of the stream, but became dry. Agricultural activities promote habitat loss through land clearing and water overextraction, which leads to soil salinization. Photo by Jorge H. Valdez-Villavicencio.



**Fig. 27.** Arroyo Santo Domingo, Baja California. **A.** Kilometers of water pipelines are used along Arroyo Santo Domingo to irrigate crops in the San Quintín valley; **B.** A well at Arroyo Santo Domingo. INEGI catalogued this arroyo as overexploited, but water extraction activities continue. *Photo by Jorge H. Valdez-Villavicencio.*



**Fig. 28.** In the San Quintín Valley, fields are irrigated for agriculture. This area was the habitat of *Anniella geronimensis* and *Aspidoscelis labialis*, both endemic species in this area. *Photo by Jorge H. Valdez-Villavicencio.*

declines (Blackburn et al. 2019; Cox et al. 2022), especially on island systems where invasive species are the main threat (Aguirre-Muñoz et al. 2016). Many of the alien species affect native species (Figs. 29–30), not only through direct predation, but also by competing for prey, modifying/eliminating habitat, and spreading disease (Holland 1994; Kats and Ferrer 2003; Bury et al. 2012).

Many species of mammals have been introduced on the islands associated with the Baja California Peninsula, some of which contribute to habitat loss and modification (e.g., goats), competition, and predation (e.g., rats, cats, and dogs). Cats prey directly on lizards and snakes, and could be their main threat on islands (Arnaud et al. 2008). Fortunately, many of these invasive species have been eradicated from several of these islands (Aguirre-Muñoz et al. 2016), but they still are present on some

of the islands, which represents a threat to the unique species in these island habitats.

In the northwestern region of the peninsula, a low abundance of amphibians, and the absence of *Rana draytonii* in particular, have been reported at sites where exotic species are present (Peralta-García et al. 2016). The same situation has been observed with the pond turtle *Actinemys pallida* in the presence of Bullfrogs (*Lithobates catesbeianus*; Valdez-Villavicencio et al., In Press). This same phenomenon occurs in many oases along the peninsula where various introduced species (e.g., *Tilapia zilli*, *Procambarus clarkii*, and *L. catesbeianus*) are found, which might be affecting the amphibian populations (Luja et al. 2016). In northeastern Baja California, the native anurans *Incilius alvarius* and *Lithobates yavapaiensis* perhaps have been extirpated due to the introductions of the Bullfrog and various fish species (Grismer 2002).





**Fig. 29.** Invasive Bullfrogs (*Lithobates catesbeianus*) at Valle de Guadalupe, Baja California. This species has dispersed throughout this valley due to growth in the wine industry, which usually includes reservoirs for irrigation or attractions for customers. Sunfish and Largemouth Bass have been released into these reservoirs, which threaten native amphibians and reptiles. *Photo by Andrea Navarro-Tiznado.*



**Fig. 30.** An adult *Hypsigena ochrorhynchus* was found in the stomach of a Bullfrog (*Lithobates catesbeianus*) at Rancho Madrigal, Ensenada, Baja California. Efforts to eradicate these frogs are being made at this site. *Photo by Jorge H. Valdez-Villavicencio.*

In this same region, a reduction in the diversity of amphibian and reptile species also has been reported in disturbed sites of the Colorado River that have been invaded by exotic vegetation (Valdez-Villavicencio et al. 2021). Introduced plants can have serious negative effects on the environment and represent another threat to the survival of reptiles, since they can significantly reduce the richness and abundance of the insects that

are the main food for many species of reptiles (Valentine et al. 2007; Schirmel et al. 2016). For example, the legless lizard *Anniella stebbinsi* appears to be affected by the invasion of ice plants (*Carpobrotus edulis* and *Mesembryanthemum crystallinum*) in the coastal dunes of northwestern Baja California (Manriquez-Gomez et al. 2021). The same situation occurs in coastal dunes between San Quintín and El Socorro, where the



**Fig. 31.** Livestock grazing at La Grulla, Sierra San Pedro Mártir, Baja California, a high-elevation meadow at 2,250 m asl. The lack of livestock management affects local herpetofaunal populations, including those of *Rana draytonii*, *Anaxyrus californicus*, and *Thamnophis elegans*. Photo by Jorge H. Valdez-Villavicencio.



**Fig. 32.** Livestock wandering along the side of Arroyo Valladares, Baja California. Photo by Anny Peralta-García.

abundance of *Anniella geronimensis* has been observed to be much lower in patches with ice plants, when compared to patches of native vegetation (APG and JHVV, unpub. data).

Invasive plants on island systems also might be affecting the survival of amphibians and reptiles. In recent years, the increase of non-native grass species has been observed on some Pacific islands. Introduced grasses have been shown to alter the structure and function of ecosystems, thereby causing negative impacts on native species (García and Clusella-Trullas 2019), since they can reduce the availability of microhabitats, and also alter the thermal quality of the habitat (Carter et al. 2015; Schlesinger et al. 2020; Lara-Reséndiz et al. 2022). For example, a low abundance of *Lampropeltis herrerae* has been observed on Todos Santos Island, perhaps caused by introduced grasses (Pampa-Ramírez 2021), in addition to a low abundance of lizards.

In other habitats such as oases, introduced plants represent a serious threat. The Rubber Vine (*Cryptostegia grandiflora*) is an aggressive invasive plant that has been introduced into at least 22 oases in Baja California Sur, and likely is affecting amphibians and reptiles associated with these unique habitats (Valentine et al. 2007; Rodríguez-Estrella et al. 2010).

**Livestock grazing.** Livestock production is an important part of the economies of both states in the Baja California Peninsula, as the percentage of land use for cattle is over 50% (SEMARNAT 2003). The effects of ranching and livestock on wildlife need to be better documented (but see Figs. 31–32). However, overgrazing likely has led to a major problem in the meadows of northwestern Baja California, causing their disappearance and impacting riparian wildlife species, including amphibians such as *Rana draytonii* and *Anaxyrus californicus* (Mellink and





**Fig. 33.** A Southwestern Pond Turtle (*Actinemys pallida*) trampled by cattle along Arroyo San Vicente, Baja California. Photo by Anny Peralta-García.

Contreras 2014; Peralta-García et al. 2016). Remnant meadows might be affected by the water quality changes associated with grazing, leading to the demise of local amphibian populations (Smalling et al. 2021). In Baja California Sur, the tropical deciduous forest has been overgrazed for over 200 years; and during this time, grazing has changed the vegetational structure and composition of the Cape Region, thus affecting wildlife through habitat loss (Jaramillo 1994; Arriaga 2006). In general, habitats with a relatively complex structures support more diverse animal communities than those with simple structures, due to the provision of a greater range of available niches that can be exploited (Pianka 1966).

Livestock grazing has been associated with a lower density and structure of the vegetation and seed production, soil compaction, the lowering of water filtration, increased erosion, as well as modification of the available oxygen, chemical composition, microorganisms, and fertility (Mellink and Contreras 2014; Jofré and Reading 2012). In the Baja California Peninsula, the abundance of three species of frogs and four species of lizards was lower in grazed areas than in ungrazed areas (Arguelles-Méndez et al. 1996; Romero-Schmidt et al. 1994; Romero-Schmidt and Ortega-Rubio 1999). The differences were attributed to a reduction in the protective cover from predators and food availability for insects. Furthermore, cattle might have a direct effect by disturbing individuals or even crushing them as they wander in their habitat. Cattle grazing had a detrimental effect on lizard populations. For example, Busack and Bury (1974) found negative effects on *Gambelia*

*wislizenii* and *Phrynosoma platyrhinos* (two species found in Baja California), because grazing had altered their preferred habitats and the availability of food.

Dead individuals of *Actinemys pallida* have been found on stream banks (Fig. 33), showing signs of being crushed by livestock (APG and JHV, pers. obs.). Grazing and trampling led to an overall decline in reptile population abundance, changes in reptile species composition, and reduced reptile diversity in the majority of the habitat types where it has been studied (Jofré and Reading 2012). However, more research is needed to understand the effect of grazing on amphibians and reptiles in the Baja California Peninsula.

**Illegal trade.** Currently, many species of amphibians and reptiles that are rare or endemic, or that inhabit particular areas such as islands, are attractive to collectors and often are illegally collected and traded, which can lead to over-collecting, consequently affecting their survival (Auliya et al. 2016; Marshall et al. 2020). The herpetofauna of the Baja California Peninsula is known to be subject to the illegal collecting and trafficking of species (Mellink 1995; Grismer 2002). Many insular endemic species are subject to illegal collection and trade. The Baja California associated islands harbor numerous endemic species that are subject to the pet trade, especially rattlesnakes (Pliego-Sánchez et al. 2021) and the Todos Santos Island Kingsnake (*Lampropeltis herrerae*). Collectors turning over rocks and snake traps have been reported on Isla Todos Santos (Mellink 1995). In 2007, APG and JHV also found several abandoned traps, and recently Pampa-





**Fig. 34.** Car and motorcycle tracks seen in the vicinity of turtle nesting sites at Punta Arena, north of Cabo Pulmo, Baja California Sur. These activities remain a common practice along these areas. *Photo by Alan Harper.*

Ramírez (2021) reported finding three more abandoned traps. However, we do not know whether this species presently continues to be attractive for illegal collection. The search for and illegal collection of reptiles also has led to the degradation of the habitat of rock-dwelling species (Goode et al. 2004, 2005), such as the rocky habitat of the snakes *Lampropeltis multifasciata* and *Lichanura trivirgata*, and rock-dwelling lizards (e.g., *Petrosaurus* and *Sauromalus*). Reports of the illegal removal of large numbers of the endemic *Petrosaurus thalassinus* in the Cape Region of Baja California Sur have been published (Grismer 2002; Lovich et al. 2009).

Recently, we have seen social media posts of people purchasing individuals of *Bipes biporus* and *Phrynosoma* species from Baja California. This practice encourages the local people to illegally (sometimes unknowingly) collect reptile species to sell to these types of buyers.

**Off-road activities.** Off-road vehicle driving (Figs. 34–35) is a common outdoor recreational activity in the Baja California Peninsula (Gaeta-Verdín 2020). The use of these types of vehicles (quads, buggies, racers, etc.) has increased significantly in recent years, but there are few regulations on how and where these recreational activities can be undertaken. Today, these activities are a common tourist attraction along the coasts of the peninsula, where rental services for these vehicles are offered. Few studies in Baja California have evaluated whether these activities affect biodiversity, but studies elsewhere have shown the negative effects on reptiles in desert habitats due to the loss of vegetational cover, a reduction in the abundance of invertebrates, and the disturbance of the daily activities of reptiles (Busack and Bury 1974; Bury et al. 1977). One example is the

alteration of the coastal dunes in northwestern Baja California (El Descanso dunes, and La Lagunita in Ensenada), where the vegetation has been lost completely due to the use of all-terrain vehicles (Rodríguez-Revelo et al. 2014a), and it surely has affected species such as *Anniella stebbinsii* and *Sceloporus zosteromus*. These types of activities also could be affecting other species, including *Phrynosoma mcallii*, *Uma notata*, and *Crotalus cerastes* (included in NOM-059), as they may be run over by off-road vehicles passing through Laguna Salada or the Cuervitos-Algodones dunes in Mexicali. The use of these vehicles in riparian areas also is a common activity, sometimes directly in the streambeds, where they affect freshwater turtles and tadpoles or amphibian egg masses. Baja California Sur is no exception. Due to the increasing amount of tourism, numerous places now offer these types of recreational activities, and mainly in coastal areas. Sea turtle nesting areas also have been affected by tourists or local people who do not respect the posted signs, and use motorcycles and cars to enter the sand dunes where turtles nest (Vanderplank et al. 2014b). High-speed off-road vehicle races are held in Baja California each year (e.g., Baja 1,000, 500, 400, and 250 mile races). Nearly 300 vehicles participate in the Baja 1,000 and travel along the dirt roads and trails along the peninsula, and even through natural protected areas. These vehicles likely are causing irreparable damage to the arid and semi-arid environments of the Baja California peninsula, since constant traffic compacts the soil, destroys the vegetation, and promotes erosion (Gaeta-Verdín 2020). Given the characteristics of these vehicles, *Scaphiopus couchii* and *Spea hammondi* burrows can be susceptible to the disturbance caused by the vehicles that generate noise and produce vibrations



**Fig. 35.** Well-traveled road along a streambed at Cañón El Alamo, Arroyo Las Palmas, Baja California. Several species of amphibians and reptiles, including Southwestern Pond Turtles (*Actinemys pallida*), inhabit this stream. *Photo by Anny Peralta-García.*

similar to rain, inducing their emergence under highly unfavorable conditions (hot and dry) that would be fatal for adults (Jennings and Hayes 1994). Another problem with this activity is that the routes are not permanent, and every year they change and affect different areas. The traffic caused by local vehicles also is a problem, as thousands of spectators also travel along the dirt roads to watch the races at different points, and they surely run over a large number of lizards and snakes, in addition to the problem of improperly disposing of their garbage (Gaeta-Verdín 2020).

**Infectious diseases.** Infectious diseases are considered one of the main threats to amphibians worldwide, resulting in the declines and local extinctions of many species. One of the main diseases is chytridiomycosis, an infectious disease caused by the pathogenic fungi *Batrachochytrium*

*dendrobatidis* and *B. salamandrivorans* (Skerratt et al. 2007; Adams et al. 2022). For reptiles, some infectious diseases also have emerged and affected wild populations through disease transmission, such as the one in snakes caused by the fungus *Ophidiomyces ophiodiicola*, and the turtle shell disease caused by *Emydomyces testavorans* (Haynes et al. 2021; Lambert et al. 2021).

Only a few studies in the Baja California Peninsula have investigated diseases in amphibians, and they have focused on *B. dendrobatidis* (Bd). Bd has been recorded in both states, with museum records detecting the pathogen as early as 1932 in Baja California (Adams et al. 2022). In the northern state, this fungus has been detected in *Anaxyrus californicus*, *A. boreas*, *Pseudacris cadaverina*, *P. hypochondriaca*, *Rana draytonii*, and the exotic *Lithobates catesbeianus*, with only *Xenopus laevis* testing negative (Peralta-García et al. 2018). In



Baja California Sur, Bd also has been detected in *L. catesbeianus* and *P. hypochondriaca* (Luja et al. 2012). Bd-positive sites occurred at elevations ranging from sea level to 2,070 m asl.

The presence of the non-native American Bullfrog (*Lithobates catesbeianus*), a competent Bd vector and reservoir host (Schloegel et al. 2012; Adams et al. 2017), has been associated with higher Bd prevalence in native anurans in Baja California (Luja et al. 2012). Increased Bd prevalence in Baja California also has been observed at higher elevations, and with greater remoteness from urban areas and agricultural land (Peralta-García et al. 2018). Adams et al. (2022) found an overall Bd prevalence of 68%, with species being an important predictor of pathogen prevalence and burden (load) both across and within sites. Species distribution models of Bd predict high suitability for the pathogen in northwestern Baja California, based on environmental factors (Bolom-Huet et al. 2019). Infections higher than >10,000 ZE (where ZE is a measure of infection intensity) have been observed in Baja California frogs, particularly in *A. boreas* and *R. draytonii*, with a higher prevalence at higher elevation sites (Peralta-García et al. 2018; Adams et al. 2022), prompting the need for further investigations of Bd in this region.

No diseases have been detected for reptiles, but follow-up studies are important because some diseases have been detected in snakes and turtles in the neighboring state of California (Haynes et al. 2021; Lambert et al. 2021).

**Climate change.** Climate change has become one of the main threats to biodiversity (Pereira et al. 2010; Bellard et al. 2012). Some of the main effects of climate change are changes in temperatures that can accelerate the loss and degradation of habitat, promote changes in the abundance and structure of communities, and alter the distribution of species, in addition to accelerating the extinction of species at different scales (Bellard et al. 2012). In the case of reptiles, many studies have examined the impact of climate change and indicate severe effects on these organisms (Sinervo et al. 2010; Meiri et al. 2013). Climate change represents a threat for most reptiles since it can reduce their hours of activity, thereby causing the alterations in many of their physiological processes, reproduction, and feeding (Sinervo et al. 2010).

In the Baja California Peninsula, species with restricted distributions or species with fossorial habits are the ones that primarily will be affected. For example, climate change effect models show that *Anniella geronimensis* and *Bipes biporus* would experience negative impacts on their distributions (Lara-Reséndiz et al. 2020). Conversely, some thermophilic and widely distributed species (e.g., *Dipsosaurus dorsalis*) might not be as threatened by climate change (Lara-Reséndiz et al. 2019). Fossorial species (such as *Anniella geronimensis* and *Bipes biporus*) may also be impacted under projected

climate change scenarios, in which reduced dispersal and mobility may be coupled with reduced suitable habitat (Lara-Reséndiz et al. 2020).

The effects of climate change could present a severe threat to insular systems, since amphibians and reptiles obviously cannot expand or modify their distributions to compensate for its effects. Among terrestrial vertebrates on islands, reports show that amphibians and reptiles could be the most affected by climate change. Estimates indicate that many species could lose close to 50% of their distribution ranges (Ureta et al. 2018). In addition to this factor, the rise in sea level due to the effects of climate change would affect many of the reptiles on islands (Bellard et al. 2013; Pliego-Sánchez et al. 2021). Although the effects of climate change on amphibians in the Baja California Peninsula have not been evaluated, we realize that changes in temperature on a global scale also will have strong effects on amphibians. These changes could affect reproduction and hibernation periods, as well as their ability to find food, alter pathogen-host dynamics, lead to increased stress from UV radiation, as well as alterations in reproduction and hibernation periods (Blaustein et al. 2010).

Species that inhabit elevations above 500 m are expected to lose a significant part of their climatically suitable area (Alves-Ferreira et al. 2022). Conversely, species that inhabit arid environments tend to expand their ranges in response to climate change. This result can be explained by the environmental characteristics of these habitats, which tend to have extreme seasonal climates with well-defined periods of drought and rain (Alves-Ferreira et al. 2022). Although the Cape Region in Baja California Sur is not particularly diverse in amphibian species, some predictions also indicate a reduction in the number of species that inhabit tropical dry forest (Ballesteros-Barrera et al. 2022).

### Conservation Status

We used the three systems of conservation assessment that were used in the previous entries in the Mexican Conservation Series (MCS; see above). These systems are SEMARNAT (2019), the IUCN Red List (<http://iucnredlist.org>), and the EVS (Wilson et al. 2013a,b). Based on the features of the Baja California Peninsula system, we updated the assessments from these three systems as necessary.

### The SEMARNAT List of Threatened Species

The Mexican Federal Government designates threatened species on the NOM-059-SEMARNAT-2010 listing. Species are classified through a risk assessment method developed by the Secretaria del Medio Ambiente y Recursos Naturales, with the last update published in 2019 (SEMARNAT 2019). The available ratings from this list are provided in Table 7 and summarized in



**Table 10.** SEMARNAT categorizations for the herpetofaunal species in the Baja California Peninsula, Mexico, arranged by family. Non-native species are excluded.

Family	Number of species	SEMARNAT categorization			
		Endangered (P)	Threatened (A)	Special Protection (Pr)	No Status (NS)
Bufonidae	6	—	1	—	5
Hylidae	2	—	—	—	2
Ranidae	3	1	—	2	—
Scaphiropodidae	2	—	—	—	2
<b>Subtotal</b>	<b>13</b>	<b>1</b>	<b>1</b>	<b>2</b>	<b>9</b>
Plethodontidae	3	—	—	2	1
<b>Subtotal</b>	<b>3</b>	<b>—</b>	<b>—</b>	<b>2</b>	<b>1</b>
<b>Total</b>	<b>16</b>	<b>1</b>	<b>1</b>	<b>4</b>	<b>10</b>
Anguidae	5	—	—	2	3
Anniellidae	2	—	—	2	—
Bipedidae	1	—	—	1	—
Crotaphytidae	5	—	—	1	4
Eublepharidae	3	—	—	1	2
Iguanidae	7	—	3	2	2
Phrynosomatidae	30	1	10	6	13
Phyllodactylidae	5	—	1	4	—
Scincidae	3	—	—	2	1
Teiidae	13	—	4	5	4
Xantusiidae	4	—	—	—	4
<b>Subtotal</b>	<b>78</b>	<b>1</b>	<b>18</b>	<b>26</b>	<b>33</b>
Charinidae	1	—	1	—	—
Colubridae	29	—	7	5	17
Dipsadidae	7	—	—	2	5
Elapidae	1	—	—	—	1
Leptotyphlopidae	2	—	—	—	2
Natricidae	4	—	3	—	1
Viperidae	12	—	2	8	2
<b>Subtotal</b>	<b>56</b>	<b>—</b>	<b>13</b>	<b>15</b>	<b>28</b>
Cheloniidae	4	4	—	—	—
Dermochelyidae	1	1	—	—	—
Emydidae	2	—	—	—	2
Testudinidae	1	—	1	—	—
<b>Subtotal</b>	<b>8</b>	<b>5</b>	<b>1</b>	<b>—</b>	<b>2</b>
<b>Total</b>	<b>142</b>	<b>6</b>	<b>32</b>	<b>41</b>	<b>63</b>
<b>Sum Total</b>	<b>158</b>	<b>7</b>	<b>33</b>	<b>45</b>	<b>73</b>

Table 10, and non-designated species are not included on the NOM-059-SEMARNAT-2010 list. This system utilizes three categories of assessment: endangered (P), threatened (A), and under special protection (Pr), and non-designated species are indicated here by using a “no status” (NS) category.

The data in Table 10 show that 85 (53.8%) of the 158 native species inhabiting the Baja California Peninsula and its adjacent islands are included in NOM-059 SEMARNAT, whereas 73 (46.2%) are not included, which could indicate either that they have not been assessed or are not considered as threatened.

In all MCS studies, the question always arises as to whether any bias is shown toward the conservation assessments of endemic species as opposed to non-endemic species using the SEMARNAT system, inasmuch as the majority of the species in a given area examined, in this case the Baja California Peninsula and its adjacent islands, remain unassessed. In order to answer this question, the pertinent data are shown in Table 11. These data show that about one-half of the

non-endemic species (42, or 51.9% of 81 total species) remain unassessed, while a slightly lower number were unassessed for the peninsular endemics (31, or 40.3% of 77 total species). For the total native herpetofauna, 74, or 46.8% of 158 species, remain unassessed. Thus, no clear bias is apparent toward the peninsular endemics.

### The IUCN System

The implementation of the system of conservation assessment established by the International Union for the Conservation of Nature has not kept pace with new species descriptions and ongoing taxonomic research. In fact, this is why the EVS system was developed—i.e., to assist in the development of conservation strategies when the IUCN system has not been applied. The data for the IUCN categorizations are shown in Table 8 and summarized in Table 12.

Of the 158 native species in the herpetofauna of the Baja California Peninsula, 130 (82.3%) have been evaluated under the IUCN system (Table 12). Of these

The herpetofauna of the Baja California Peninsula

**Table 11.** Comparison of SEMARNAT and distributional categorizations for the Baja California Peninsula herpetofauna. Non-native species are excluded.

Distributional category	SEMARNAT category				
	Endangered (P)	Threatened (A)	Special Protection (Pr)	No Status (NS)	Total
Non-endemic Species (NE)	7	13	19	42	81
Peninsular endemic Species (PE)	—	20	26	31	77
Total	7	33	45	73	158

130 species, 15 (11.5%) have been placed in one of the three “threat categories,” including three in the CR category, four in the EN category, and eight in the VU category. The three species in the CR category are the snake *Crotalus catalinensis*, a peninsular endemic species; and the turtles *Eretmochelys imbricata* and *Dermochelys coriacea*, both non-endemic marine species. The four species in the EN category are the anuran *Anaxyrus californicus*, a non-endemic species;

the lizards *Anniella geronimensis* and *Sauromalus hispidus*, both peninsular endemic species; and the turtle *Chelonia mydas*, a non-endemic marine species. The eight VU species are the lizards *Sauromalus klauberi*, *Uta encantadae*, *U. lowei*, *U. tumidarostra*, *Aspidoscelis catalinensis*, and *A. labialis*, all peninsular endemic species, and the turtles *Lepidochelys olivacea* and *Actinemys pallida*, both non-endemic species.

Of the 115 species placed in the “lower risk categories”

**Table 12.** IUCN Red List categorizations for herpetofaunal families in the Baja California Peninsula, Mexico. Non-native species are excluded. Shaded columns to the left are the “threat categories,” and those to the right are the categories for which too little information on conservation status exists to allow the taxa to be placed in any other IUCN category, or they have not been evaluated.

Family	Number of species	IUCN Red List categorization						
		Critically Endangered	Endangered	Vulnerable	Near Threatened	Least Concern	Data Deficient	Not Evaluated
Bufonidae	6	—	1	—	—	5	—	—
Hylidae	2	—	—	—	—	2	—	—
Ranidae	3	—	—	—	2	1	—	—
Scaphiropodidae	2	—	—	—	1	1	—	—
Subtotal	13	—	1	—	3	9	—	—
Plethodontidae	3	—	—	—	—	3	—	—
Subtotal	3	—	—	—	—	3	—	—
Total	16	—	1	—	3	12	—	—
Anguidae	5	—	—	—	—	5	—	—
Anniellidae	2	—	1	—	—	—	—	1
Bipedidae	1	—	—	—	—	1	—	—
Crotaphytidae	5	—	—	—	—	5	—	—
Eublepharidae	3	—	—	—	—	3	—	—
Iguanidae	7	—	1	1	1	3	—	1
Phrynosomatidae	30	—	—	3	2	24	—	1
Phyllodactylidae	5	—	—	—	1	4	—	—
Scincidae	3	—	—	—	—	3	—	—
Teiidae	13	—	—	2	—	10	—	1
Xantusiidae	4	—	—	—	—	1	—	3
Subtotal	78	—	2	6	4	59	—	7
Charinidae	1	—	—	—	—	1	—	—
Colubridae	29	—	—	—	—	18	3	8
Dipsadidae	7	—	—	—	—	4	—	3
Elapidae	1	—	—	—	—	1	—	—
Leptotyphlopidae	2	—	—	—	—	1	—	1
Natricidae	4	—	—	—	—	4	—	—
Viperidae	12	1	—	—	—	7	—	4
Subtotal	56	1	—	—	—	36	3	16
Cheloniidae	4	1	1	1	—	1	—	—
Dermochelyidae	1	1	—	—	—	—	—	—
Emydidae	2	—	—	1	—	—	—	1
Testudinidae	1	—	—	—	—	—	—	1
Subtotal	8	2	1	2	—	1	—	1
Total	142	3	3	8	4	96	3	25
Sum total	158	3	4	8	7	108	3	25
Category total	158	15			115		28	

(NT and LC), only seven are in the NT category, with the remaining 108 species in the LC category (Table 12). The seven NT species are the anurans *Rana draytonii*, *Rana boylei*, and *Spea hammondi*; all non-endemic species, and the lizards are *Sauromalus slevini*, *Phrynosoma mcallii*, *Uma notata*, and *Phyllodactylus unctus*, which include two peninsular endemic species and two non-endemic species. The 108 LC species make up 68.4% of the 158 native species in the Baja California Peninsula. Finally, 28 species have not been assessed using the IUCN system, including three allocated to the DD category. These 28 species comprise 17.7% of the native species, and their assessments using the EVS system are given below.

### The EVS System

As discussed in all the earlier MCS studies, the Environmental Vulnerability System (EVS) initially was developed for use in the conservation evaluation of the herpetofauna in the country of Honduras (Wilson and McCranie 2004). Those authors created this system

as a means for determining the conservation status of the members of a herpetofauna whose knowledge was insufficient when using the IUCN system. When the work of the MCS began in 2013, it was evident that the EVS could be applied to the Mexican herpetofauna just as easily as it had for the Honduran herpetofauna. Subsequently, this system has been employed in all of the MCS studies to date (see above), including the present one. Thus, the EVS values for the 152 native non-marine species of the Baja California Peninsula are shown in Table 8 and summarized in Table 13.

The EVS values range from 3 to 20. The most frequent values (applied to 10 or more species) are 9 (11), 10 (10), 11 (15), 12 (14), 14 (15), 15 (15), 16 (18), and 17 (29). Collectively, these eight values were applied to 127 of the 152 native non-marine species (83.6%). The lowest score of 3 was ascertained for two anuran species (*Scaphiopus couchii* and *Anaxyrus punctatus*) and the highest score of 20 was assigned to the Todos Santos Island Kingsnake (*Lampropeltis herrerae*).

The EVS scores are grouped into three categories

**Table 13.** Environmental Vulnerability Scores (EVS) for the herpetofaunal species in the Baja California Peninsula, Mexico, arranged by family. The shaded area to the left encompasses low vulnerability scores, and the one to the right high vulnerability scores. Non-native species are excluded.

Family	Number of species	Environmental Vulnerability Scores																	
		3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Bufonidae	6	1	1	—	—	1	—	—	1	2	—	—	—	—	—	—	—	—	—
Hylidae	2	—	—	—	—	—	—	1	—	1	—	—	—	—	—	—	—	—	—
Ranidae	3	—	—	—	—	—	—	—	—	1	2	—	—	—	—	—	—	—	—
Scaphiopodidae	2	1	1	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—
<b>Subtotal</b>	<b>13</b>	<b>2</b>	<b>1</b>	—	—	<b>1</b>	—	<b>1</b>	<b>1</b>	<b>5</b>	<b>2</b>	—	—	—	—	—	—	—	—
Plethodontidae	3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
<b>Subtotal</b>	<b>3</b>	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
<b>Total</b>	<b>16</b>	<b>2</b>	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Anguidae	5	—	—	—	—	—	—	—	1	—	—	—	1	1	2	—	—	—	—
Anniellidae	2	—	—	—	—	—	—	—	—	1	—	—	1	—	—	—	—	—	—
Bipedidae	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—
Crotaphytidae	5	—	—	—	—	—	—	1	—	1	1	—	—	—	2	—	—	—	—
Eublepharidae	3	—	—	—	—	—	—	1	1	—	—	—	—	—	1	—	—	—	—
Iguanidae	7	—	—	—	—	—	—	—	—	—	1	1	1	—	2	2	—	—	—
Phrynosomatidae	30	—	—	1	—	2	—	2	1	1	4	2	4	3	3	7	—	—	—
Phyllodactylidae	5	—	—	—	—	—	—	—	1	—	—	—	—	2	1	1	—	—	—
Scincidae	3	—	—	—	—	—	—	—	1	1	—	1	—	—	—	—	—	—	—
Teiidae	13	—	—	—	—	—	1	—	1	—	—	—	1	1	2	7	—	—	—
Xantusiidae	4	—	—	—	—	—	—	—	—	2	—	—	—	2	—	—	—	—	—
<b>Subtotal</b>	<b>78</b>	<b>0</b>	<b>0</b>	<b>1</b>	<b>0</b>	<b>2</b>	<b>1</b>	<b>4</b>	<b>6</b>	<b>6</b>	<b>6</b>	<b>4</b>	<b>8</b>	<b>9</b>	<b>13</b>	<b>17</b>	<b>0</b>	<b>1</b>	<b>0</b>
Charinidae	1	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—
Colubridae	29	—	—	1	1	1	4	3	—	2	4	1	3	3	1	3	1	—	1
Dipsadidae	7	—	1	—	—	—	—	—	2	1	—	—	—	—	3	—	—	—	—
Leptotyphlopidae	2	—	—	—	—	—	1	—	—	—	—	—	1	—	—	—	—	—	—
Natricidae	4	—	—	—	—	—	—	1	—	1	1	—	1	—	—	—	—	—	—
Viperidae	12	—	—	—	—	—	—	2	—	—	1	2	—	1	1	—	1	4	—
<b>Subtotal</b>	<b>55</b>	<b>0</b>	<b>1</b>	<b>1</b>	<b>1</b>	<b>1</b>	<b>5</b>	<b>6</b>	<b>3</b>	<b>4</b>	<b>6</b>	<b>3</b>	<b>5</b>	<b>4</b>	<b>5</b>	<b>3</b>	<b>2</b>	<b>4</b>	<b>1</b>
Emydidae	2	—	—	—	—	—	—	—	—	—	—	1	—	1	—	—	—	—	—
Testudinidae	1	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—
<b>Subtotal</b>	<b>3</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>1</b>	<b>0</b>	<b>2</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>
<b>Total</b>	<b>136</b>	<b>0</b>	<b>1</b>	<b>2</b>	<b>1</b>	<b>3</b>	<b>6</b>	<b>10</b>	<b>9</b>	<b>10</b>	<b>12</b>	<b>8</b>	<b>13</b>	<b>15</b>	<b>18</b>	<b>20</b>	<b>2</b>	<b>5</b>	<b>1</b>
<b>Sum total</b>	<b>152</b>	<b>2</b>	<b>2</b>	<b>2</b>	<b>1</b>	<b>4</b>	<b>6</b>	<b>11</b>	<b>10</b>	<b>15</b>	<b>14</b>	<b>9</b>	<b>15</b>	<b>15</b>	<b>18</b>	<b>20</b>	<b>2</b>	<b>5</b>	<b>1</b>
<b>Category total</b>	<b>152</b>	<b>28</b>						<b>48</b>					<b>76</b>						



**Table 14.** Comparison of Environmental Vulnerability Scores (EVS) and IUCN categorizations for members of the herpetofauna of the Baja California Peninsula, Mexico. Non-native species are excluded. The shaded area at the top encompasses low vulnerability scores, and the one at the bottom high vulnerability scores.

EVS	IUCN category							Total
	Critically Endangered	Endangered	Vulnerable	Near Threatened	Least Concern	Data Deficient	Not Evaluated	
3	—	—	—	—	2	—	—	2
4	—	—	—	—	2	—	—	2
5	—	—	—	—	2	—	—	2
6	—	—	—	—	1	—	—	1
7	—	—	—	—	4	—	—	4
8	—	—	—	—	5	—	1	6
9	—	—	—	—	10	—	1	11
10	—	—	—	—	9	—	1	10
11	—	1	—	2	10	—	2	15
12	—	—	—	1	10	—	3	14
13	—	—	1	—	7	—	1	9
14	—	2	—	—	8	—	5	15
15	—	—	1	3	5	—	6	15
16	—	—	—	1	15	—	2	18
17	—	—	5	—	12	2	1	20
18	—	—	—	—	1	1	—	2
19	1	—	—	—	2	—	2	5
20	—	—	—	—	1	—	—	1
Total	1	3	7	7	106	3	25	152

of low, medium, and high vulnerability. As a result, the summary values (Table 13) increase from low vulnerability (28 species) to medium vulnerability (48 species), and then to high vulnerability (76 species). Typically, this pattern is characteristic of herpetofaunas containing more endemic than non-endemic species, although this is not the case with the herpetofauna of the Baja California Peninsula, in which there are 83 non-endemic species and 75 endemic species. However, this pattern could be due to the high level of island endemics that have high vulnerability values.

The numbers of species in the herpetofauna of the Baja California Peninsula for each IUCN/EVS score combination are shown in Table 14. These data illustrate that although both systems agree on the low vulnerability category and Least Concern category for 26 species (17%), they differ in the remaining categories, as only 11 of the 76 high vulnerability species (14.5%) are placed into one of the three IUCN “threat categories” (CR, EN, or VU). As was found in all other MCS studies, the results of the application of the IUCN and EVS systems of conservation assessment do not correspond well with

one another. Of the 152 species that can be assessed by both the IUCN and EVS systems, only three have been allocated to the IUCN DD category (Table 15). These are three peninsular endemic snake species (*Lampropeltis catalinensis*, *Masticophis barbouri*, and *Rhinocheilus etheridgei*), which have respective EVS scores of 18, 17, and 17. Based on the arguments presented in previous MCS studies, we suggest that once these species are evaluated by the IUCN, they should be relegated to the CR (*Lampropeltis catalinensis*) and EN (*Rhinocheilus etheridgei* and *Masticophis barbouri*) categories.

Twenty-five species (15.8% of the 158 native species) have not been evaluated by the IUCN system. These 25 species include seven lizards, 16 snakes, and two turtles. The majority of these species (15 of 25, or 60.0%) are peninsular endemics, and the remainder (10, or 40%) are non-endemics. These species are allocated to the three EVS categories of vulnerability as follows: two low (8.0%); seven medium (28.0%); and 16 high (64.0%). Based on the vulnerability values, species with an EVS of 17 and greater might be placed in the CR category;

**Table 15.** Environmental Vulnerability Scores (EVS) for members of the herpetofauna of the Baja California Peninsula, Mexico, that are allocated to the IUCN Data Deficient category. \*\* = peninsular endemic.

Taxon	Environmental Vulnerability Score (EVS)			
	Geographic distribution	Ecological distribution	Reproductive mode/ Degree of persecution	Total score
<i>Lampropeltis catalinensis</i> **	6	8	4	18
<i>Masticophis barbouri</i> **	5	8	4	17
<i>Rhinocheilus etheridgei</i> **	6	8	3	17



**No. 1.** *Anaxyrus californicus* (Camp, 1915). The Arroyo Toad is found “west of the deserts in southern California (USA) near Santa Margarita in San Luis Obispo County south into northern Baja California (Mexico), at least as far south as Arroyo San Simón, just south of San Quintín” (Frost 2022). This individual came from Rancho Meling, Sierra San Pedro Mártir, in the municipality of San Quintín. In this study its EVS was estimated as 11, placing it in the upper portion of the medium vulnerability category. The IUCN has assessed its conservation status as Endangered (EN) and SEMARNAT lists it as Threatened (A). *Photo by Ivan Parr.*



**No. 2.** *Pseudacris hypochondriaca* (Hallowell, 1854). The Baja California Chorus Frog ranges from “southern California, western and southwestern Nevada, and adjacent northwestern Arizona (Mohave County) south to the southern tip of Baja California peninsula, Mexico” (Frost 2022). This individual was found at Rancho Meling, Sierra San Pedro Mártir, in the municipality of San Quintín. In this study its EVS was determined as 9, placing it at the upper limit of the low vulnerability category. This species has not been evaluated by the IUCN or SEMARNAT. *Photo by Jorge H. Valdez-Villavicencio.*



**No. 3.** *Rana draytonii* (Baird and Girard, 1852). The California Red-legged Frog is distributed from “Mendocino County (California, USA) south along the Pacific coast of the USA to the vicinity of Arroyo Santo Domingo in northern Baja California (Mexico)” (Frost 2022). This individual was found at Rancho Meling, Sierra San Pedro Mártir, in the municipality of San Quintín. In this study its EVS was indicated as 11, placing it in the medium vulnerability category. The IUCN evaluated its status as Near Threatened (NT), and this species is listed by SEMARNAT as in danger of extinction (P). *Photo by J.A. Soriano.*



**No. 4.** *Aneides lugubris* (Hallowell, 1849). The Arboreal Salamander ranges “from sea level to near 1,270 m in elevation and ranges from Eureka in Humboldt County, California, south through the Coast Ranges, terminating near Valle Santo Tomás in northwestern Baja California. It also occurs on the Coronado Norte island” (Grismer 2002: 56). This individual came from La Misión, Baja California, in the municipality of Ensenada. In this study its EVS is listed as 14, placing it at the lower limit of the high vulnerability category. The IUCN judged its conservation status as Least Concern (LC), and SEMARNAT lists it as a species of Special Protection (Pr). *Photo by Jorge H. Valdez-Villavicencio.*

## The herpetofauna of the Baja California Peninsula

**Table 16.** Environmental Vulnerability Scores (EVS) for members of the herpetofauna of the Baja California Peninsula, Mexico, that are currently not evaluated (NE) by the IUCN. Non-native taxa are excluded. \*\* = peninsular endemic.

Taxon	Environmental Vulnerability Score (EVS)			
	Geographic distribution	Ecological distribution	Reproductive mode/ Degree of persecution	Total score
<i>Anniella stebbinsi</i>	4	6	1	11
<i>Dipsosaurus catalinensis</i> **	6	8	3	17
<i>Phrynosoma cerroense</i> **	5	6	3	14
<i>Aspidoscelis maximus</i> **	5	6	3	14
<i>Xantusia gilberti</i> **	5	8	2	15
<i>Xantusia sherbrookei</i> **	5	8	2	15
<i>Xantusia wigginsi</i>	2	7	2	11
<i>Lampropeltis multifasciata</i>	2	7	5	14
<i>Masticophis fuliginosus</i>	2	3	4	9
<i>Sonora annulata</i>	4	8	2	14
<i>Sonora cincta</i> **	2	4	2	8
<i>Sonora fasciata</i> **	5	5	2	12
<i>Sonora mosaueri</i> **	5	5	2	12
<i>Sonora punctatissima</i> **	5	8	2	15
<i>Sonora straminea</i> **	5	8	2	15
<i>Hypsiglena catalinae</i> **	6	8	2	16
<i>Hypsiglena marcosensis</i> **	6	8	2	16
<i>Hypsiglena ochrorhynchus</i>	4	4	2	10
<i>Rena boettgeri</i> **	5	8	1	14
<i>Crotalus helleri</i>	4	3	5	12
<i>Crotalus polisi</i> **	6	8	5	19
<i>Crotalus pyrrhus</i>	4	4	5	13
<i>Crotalus thalassoporus</i> **	6	8	5	19
<i>Trachemys nebulosa</i> **	5	7	3	15
<i>Gopherus morafkai</i>	4	5	6	15

which includes *Dipsosaurus catalinensis* (17), *Crotalus polisi* (19), and *C. thalassoporus* (19). All three of these species are peninsular endemics. Vulnerability values of 15 and 16 can be allocated to the EN category, including *Gopherus morafkai* (15), *Xantusia gilberti* (15), *X. sherbrookei* (15), *Sonora punctatissima* (15), *Sonora straminea* (15), *Trachemys nebulosa* (15), *Hypsiglena catalinae* (16), and *Hypsiglena marcosensis* (16). All but one of these species (*G. morafkai*) are peninsular endemics. Species with an EVS of 14 could be placed in the VU category, including *Phrynosoma cerroense*, *Aspidoscelis maximus*, *Lampropeltis multifasciata*, *Sonora annulata*, and *Rena boettgeri*. The first of these two species and the last one are peninsular endemics. The species with an EVS of 10 to 13 can be allocated to the NT category, including *Anniella stebbinsi* (11), *Xantusia wigginsi* (11), *Sonora fasciata* (12), *Sonora mosaueri* (12), *Hypsiglena ochrorhynchus* (10), *Crotalus helleri* (12), and *C. pyrrhus* (13). Only two of these seven species (*S. fasciata* and *S. mosaueri*) are peninsular endemics. Finally, the two species with an EVS of 3 to 9 can be placed in the LC category (*Sonora cincta* and *Masticophis fuliginosus*).

The largest number of species in the Baja California Peninsula herpetofauna that can be assigned an EVS are placed in the IUCN LC category (106 species; see Table

17), even though their EVS values range from 3 to 20, the range found in the entire herpetofauna of the Baja California Peninsula, as well as the entire theoretical EVS range. Of these 106 species, 47 (44.3%) are peninsular endemics, and the remaining 59 (55.7%) are non-endemics. As indicated in the above paragraphs dealing with the NE species, we suggest that the species with EVS scores of 3 to 9 might be allocated to the LC category, 10 to 13 to the NT category, 14 to the VU category, 15 and 16 to the EN category, and 17 to 20 to the CR category. Accordingly, the following species numbers might be placed in the IUCN categories as follows: LC (26), NT (36), VU (8), EN (20), and CR (16). We recognize that the EVS values will not always correspond with IUCN or SEMARNAT categories. The IUCN and EVS categories evaluate the population along the entire distribution of the species. As for the SEMARNAT system, it only lists threatened species, so species with EVS values lower than 9 are not expected to appear in the NOM-059-SEMARNAT 2010. It remains unknown, however, whether their omission is due to a lack of evaluation or because their populations are not threatened.

In general, the EVS values for amphibians are assigned lower values, with only two of the 16 native species scoring in the high vulnerability category (14 or higher). The two amphibians with high values are the





**No. 5.** *Batrachoseps major* Camp, 1915. The Garden Slender Salamander is distributed from “Los Angeles County south to the vicinity of El Rosario in northwestern Baja California. It also occurs on the Pacific islands Coronado (Norte, Medio, and Sur), and Todos Santos Sur” (Grismer 2002: 58). This individual was found at Rancho Las Dos Cumbres, Tecate, Baja California, in the municipality of Tecate. In this study its EVS was calculated as 14, placing it at the lower limit of the high vulnerability category. The IUCN assigned this salamander to the Least Concern (LC) category, but this species is not listed by SEMARNAT. *Photo by Anny Peralta-García.*



**No. 6.** *Ensatina eschscholtzii* Gray, 1850. The Monterey Salamander “ranges along the Pacific coast of North America from southwestern British Columbia south to at least 22 km south of Ensenada in northwestern Baja California” (Grismer 2002: 60; Peralta-García and Valdez-Villavicencio 2004). This individual came from La Misión, Baja California, in the municipality of Ensenada. The species EVS was estimated as 13, placing it at the higher limit of the medium vulnerability category. The IUCN assessed its conservation status as Least Concern (LC), and SEMARNAT considers it as a species of Special Protection (Pr). *Photo by Jorge H. Valdez-Villavicencio.*



**No. 7.** *Elgaria nana* (Fitch, 1934). The Islas Coronado Alligator Lizard is known from all the islands of the Islas Coronado archipelago on the coast of northwestern Baja California. This individual was encountered on Isla Coronado Sur, Baja California, in the municipality of Tijuana. In this study its EVS was determined as 16, placing it in the middle portion of the high vulnerability category. The IUCN assessed its conservation status as Least Concern (LC), and it is not listed by SEMARNAT. *Photo by Jorge H. Valdez-Villavicencio.*



**No. 8.** *Elgaria paucicarinata* (Fitch, 1934). The San Lucan Alligator Lizard “is restricted to the mountains and foothill regions of the Cape Region of Baja California” (Grismer 2002: 248). This individual came from Arroyo La Junta, Sierra La Laguna, Baja California Sur, in the municipality La Paz. In this study its EVS is indicated as 14, placing it at the lower limit of the high vulnerability category. The IUCN assessed its conservation status as Least Concern (LC), and SEMARNAT designates it as a species of Special Protection (Pr). *Photo by Jorge H. Valdez-Villavicencio.*

## The herpetofauna of the Baja California Peninsula

**Table 17.** Environmental Vulnerability Scores (EVS) for members of the herpetofauna of the Baja California Peninsula, Mexico, that are assigned to the IUCN Least Concern (LC) category. Non-native and marine taxa are not included. \*\* = peninsular endemic.

Taxon	Environmental Vulnerability Score (EVS)			
	Geographic distribution	Ecological distribution	Reproductive mode/ Degree of persecution	Total score
<i>Anaxyrus boreas</i>	2	4	1	7
<i>Anaxyrus cognatus</i>	1	2	1	4
<i>Anaxyrus punctatus</i>	1	1	1	3
<i>Anaxyrus woodhousii</i>	3	6	1	10
<i>Incilius alvarius</i>	4	6	1	11
<i>Pseudacris cadaverina</i>	4	6	1	11
<i>Pseudacris hypochondriaca</i>	4	4	1	9
<i>Lithobates yavapaiensis</i>	4	7	1	12
<i>Scaphiopus couchii</i>	1	1	1	3
<i>Aneides lugubris</i>	3	7	4	14
<i>Batrachoseps major</i>	4	6	4	14
<i>Ensatina eschscholtzii</i>	3	6	4	13
<i>Elgaria cedrosensis</i> **	5	8	3	16
<i>Elgaria multicarinata</i>	3	4	3	10
<i>Elgaria nana</i> **	5	8	3	16
<i>Elgaria paucicarinata</i> **	5	6	3	14
<i>Elgaria velazquezii</i> **	5	7	3	15
<i>Bipes biporus</i> **	5	8	6	19
<i>Crotaphytus grismeri</i> **	5	8	3	16
<i>Crotaphytus insularis</i> **	5	8	3	16
<i>Crotaphytus vestigium</i>	2	4	3	9
<i>Gambelia copeii</i> **	2	6	3	11
<i>Gambelia wislizenii</i>	3	6	3	12
<i>Coleonyx gypsicolus</i> **	6	8	2	16
<i>Coleonyx switaki</i>	2	6	2	10
<i>Coleonyx variegatus</i>	4	3	2	9
<i>Ctenosaura hemilopha</i> **	5	7	4	16
<i>Dipsosaurus dorsalis</i>	4	5	3	12
<i>Sauromalus ater</i>	4	6	3	13
<i>Callisaurus draconoides</i>	4	5	3	12
<i>Petrosaurus mearnsi</i>	2	5	3	10
<i>Petrosaurus repens</i> **	5	6	3	14
<i>Petrosaurus slevini</i> **	5	8	3	16
<i>Petrosaurus thalassinus</i> **	5	6	6	17
<i>Phrynosoma blainvillii</i>	3	6	3	12
<i>Phrynosoma coronatum</i> **	5	4	3	12
<i>Phrynosoma platyrhinos</i>	3	7	3	13
<i>Sceloporus angustus</i> **	5	8	3	16
<i>Sceloporus grandaevus</i> **	6	8	3	17
<i>Sceloporus hunsakeri</i> **	5	6	3	14
<i>Sceloporus licki</i> **	5	5	3	13
<i>Sceloporus lineatulus</i> **	6	8	3	17
<i>Sceloporus magister</i>	1	5	3	9
<i>Sceloporus occidentalis</i>	3	5	3	11
<i>Sceloporus orcutti</i>	2	2	3	7
<i>Sceloporus vandenburgianus</i>	4	7	3	14
<i>Sceloporus zosteromus</i> **	5	4	3	12
<i>Urosaurus graciosus</i>	4	8	3	15
<i>Urosaurus lahtelai</i> **	5	8	3	16
<i>Urosaurus nigricaudus</i>	2	2	3	7
<i>Urosaurus ornatus</i>	1	5	3	9
<i>Uta squamata</i> **	6	8	3	17
<i>Uta stansburiana</i>	1	1	3	5
<i>Phyllodactylus bugastrolepis</i> **	6	8	3	17

**Table 17 (continued).** Environmental Vulnerability Scores (EVS) for members of the herpetofauna of the Baja California Peninsula, Mexico, that are assigned to the IUCN Least Concern (LC) category. Non-native and marine taxa are not included. \*\* = peninsular endemic.

Taxon	Environmental Vulnerability Score (EVS)			
	Geographic distribution	Ecological distribution	Reproductive mode/ Degree of persecution	Total score
<i>Phyllodactylus nocticolus</i>	2	5	3	10
<i>Phyllodactylus partidus</i> **	5	8	3	16
<i>Phyllodactylus xanti</i> **	5	7	3	15
<i>Plestiodon gilberti</i>	3	6	2	11
<i>Plestiodon lagunensis</i> **	5	6	2	13
<i>Plestiodon skiltonianus</i>	3	5	2	10
<i>Aspidoscelis camus</i> **	6	8	3	17
<i>Aspidoscelis carmenensis</i> **	6	8	3	17
<i>Aspidoscelis celeripes</i> **	5	8	3	16
<i>Aspidoscelis ceralbensis</i> **	6	8	3	17
<i>Aspidoscelis danheimae</i> **	6	8	3	17
<i>Aspidoscelis espiritensis</i> **	5	8	3	16
<i>Aspidoscelis franciscensis</i> **	6	8	3	17
<i>Aspidoscelis hyperythrus</i>	2	5	3	10
<i>Aspidoscelis pictus</i> **	6	8	3	17
<i>Aspidoscelis tigris</i>	3	2	3	8
<i>Xantusia henshawi</i>	4	5	2	11
<i>Lichanura trivirgata</i>	4	3	3	10
<i>Arizona elegans</i>	1	1	3	5
<i>Arizona pacata</i> **	5	6	3	14
<i>Bogertophis rosaliae</i>	2	5	4	11
<i>Lampropeltis californiae</i>	4	1	4	9
<i>Lampropeltis herrerae</i> **	6	8	6	20
<i>Masticophis aurigulus</i> **	5	6	4	15
<i>Masticophis flagellum</i>	1	3	4	8
<i>Masticophis lateralis</i>	3	5	4	12
<i>Phyllorhynchus decurtatus</i>	4	5	3	12
<i>Pituophis catenifer</i>	1	1	5	7
<i>Pituophis insulanus</i> **	6	6	5	17
<i>Pituophis vertebralis</i> **	5	3	5	13
<i>Rhinocheilus lecontei</i>	1	3	4	8
<i>Salvadora hexalepis</i>	4	2	3	9
<i>Sonora savagei</i> **	6	8	2	16
<i>Sonora semiannulata</i>	3	1	2	6
<i>Tantilla planiceps</i>	2	3	3	8
<i>Trimorphodon lyrophanes</i>	2	4	5	11
<i>Diadophis punctatus</i>	1	1	2	4
<i>Hypsiglena chlorophaea</i>	3	5	2	10
<i>Hypsiglena gularis</i> **	6	8	2	16
<i>Hypsiglena slevini</i> **	5	4	2	11
<i>Rena humilis</i>	4	3	1	8
<i>Thamnophis elegans</i>	3	8	3	14
<i>Thamnophis hammondi</i>	4	5	3	12
<i>Thamnophis marcianus</i>	1	5	3	9
<i>Thamnophis validus</i> **	5	3	3	11
<i>Crotalus angelensis</i> **	6	7	5	18
<i>Crotalus atrox</i>	1	3	5	9
<i>Crotalus cerastes</i>	4	7	5	16
<i>Crotalus enyo</i> **	5	3	5	13
<i>Crotalus lorenzoensis</i> **	6	8	5	19
<i>Crotalus mitchellii</i> **	5	5	5	15
<i>Crotalus ruber</i>	2	2	5	9





**No. 9.** *Anniella geronimensis* Shaw, 1940. The Baja California Legless Lizard “ranges along the coastal aeolian dune regions of northwestern Baja California, from approximately 6 km north of Colonia Guerrero south to just south of Punta Baja at the northern edge of Bahía El Rosario. It is also known from the Pacific islands of San Gerónimo and San Martín.” (Grismer 2002: 242). This individual was encountered at San Quintín, Baja California, in the municipality of San Quintín. In this study its EVS is noted as 14, placing it at the lower limit of the high vulnerability category. The IUCN judged its conservation status as Endangered (EN), and SEMARNAT lists it as a species of Special Protection (Pr). *Photo by Jorge H. Valdez-Villavicencio.*



**No. 10.** *Bipes biporus* (Cope, 1894). The Five-toed Worm Lizard is distributed “throughout the western portion of the southern half of Baja California peninsula, west of the Peninsular Ranges, from approximately 17 km north of Jesús María, where the Sierra Columbia contacts the Pacific coast, south to Todos Santos (Mahrtdt et al. 2022)...At the Isthmus of La Paz, its distribution extends east across the low, sandy flats and contacts the Gulf coast at Bahía de La Paz” (Grismer 2002: 254). It also occurs on the Pacific island of Magdalena (Peralta-García et al. 2007). This individual was found at La Paz, Baja California Sur, in the municipality of La Paz. In this study its EVS was determined as 19, placing it near the higher limit of the high vulnerability category. The IUCN assessed its conservation status as Least Concern (LC), and SEMARNAT designates it as a species of Special Protection (Pr). *Photo by Jorge H. Valdez-Villavicencio.*



**No. 11.** *Crotaphytus insularis* Van Denburgh and Slevin, 1921. The Isla Ángel de la Guarda Collared Lizard is endemic to Isla Ángel de la Guarda in the Gulf of California in the municipality of Mexicali (Grismer 2002). Its EVS was assessed as 16, placing it in the middle of the high vulnerability category. The IUCN evaluated its conservation status as Least Concern (LC), but this lizard is not listed by SEMARNAT. *Photo by Jorge H. Valdez-Villavicencio.*



**No. 12.** *Gambelia copeii* (Yarrow, 1882). The Baja California Leopard Lizard “is endemic to Baja California peninsula and ranges from extreme southern San Diego County, California, south to at least Todos Santos on the west coast of the Cape Region” (Grismer 2002: 114). This individual came from 20 km NW of San Juanico, Baja California Sur, in the municipality of Comondú. In this study its EVS was estimated as 11, placing it in the lower portion of the medium vulnerability category. The IUCN judged its conservation status as Least Concern (LC), but this species is not listed by SEMARNAT. *Photo by Jorge H. Valdez-Villavicencio.*



**No. 13.** *Coleonyx switaki* (Murphy, 1974). Switak's Banded Gecko "ranges along the desert foothills of the Peninsular Ranges from at least northern San Diego County, California, south to just north of Santa Rosalía" (Grismer 2002: 199) in Baja California Sur. This individual was located in San Ignacio, Baja California Sur, in the municipality of Mulegé. In this study its EVS is noted as 10, placing it at the lower limit of the medium vulnerability category. The IUCN determined its conservation status as Least Concern (LC), but this gecko is not listed by SEMARNAT. *Photo by Tim Warfel.*



**No. 14.** *Ctenosaura hemilopha* (Cope, 1863). The Cape Spiny-tailed Iguana "ranges from near Loreto south along the Sierra la Giganta to the west coast near Arroyo Seco and through the Cape Region...In the Gulf of California, *C. hemilopha* is known only from Isla Cerralvo..." (Grismer 2002: 117). This individual came from Sierra La Gata, Baja California Sur, in the municipality of La Paz. In this study its EVS was calculated as 16, placing it in the middle portion of the high vulnerability category. The IUCN determined its conservation status as Least Concern (LC), but SEMARNAT considers it to be a species of Special Protection (Pr). *Photo by Jorge H. Valdez-Villavicencio.*



**No. 15.** *Sauromalus hispidus* Stejneger, 1891. The Spiny Chuckwalla "is known from the Gulf islands of Ángel de la Guarda, Cabeza de Caballo, Flecha, Granito, La Ventana, Mejía, Piojo, Pond, San Lorenzo Norte, San Lorenzo Sur, and Smith" (Grismer 2002: 128). This individual was found on Isla Ángel de la Guarda, Baja California, in the municipality of Mexicali. In this study its EVS was determined as 14, placing it at the lower limit of the high vulnerability category. The IUCN assessed its conservation status as Endangered (EN), and SEMARNAT noted it as Threatened (A). *Photo by Jorge H. Valdez-Villavicencio.*



**No. 16.** *Callisaurus draconoides* Blainville, 1835. The Zebra-tailed Lizard "ranges throughout the Sonoran and Mojave deserts of the southwestern United States and northern Mexico south to southern Sinaloa and all the arid regions of Baja California" (Grismer 2002: 136). This individual was encountered at Guerrero Negro, Baja California Sur, in the municipality of Mulegé. In this study its EVS is listed as 12, placing it in the upper portion of the medium vulnerability category. The IUCN assessed its conservation status as Least Concern (LC), and SEMARNAT designates it as Threatened (A). *Photo by Alan Harper.*

The herpetofauna of the Baja California Peninsula

**Table 18.** Number of herpetofaunal species in three distributional status categories among the 10 physiographic regions of the Baja California Peninsula, Mexico. Rank was determined by adding the state and country endemics.

Geographic region	Distributional Status Category			Total	Rank order
	Non-endemic	Peninsular Endemic	Non-native		
CR	47	8	5	60	7
LCVR	59	5	4	68	8
BCCFR	27	—	—	27	9
VR	43	18	3	64	5
CGCR	35	24	3	62	3
MR	32	18	1	51	5
ATR	32	26	7	65	2
SLLR	18	21	2	41	4
PIR	32	15	—	47	6
GIR	32	50	2	84	1

salamanders *Aneides lugubris* and *Batrachoseps major*, both with an EVS of 14 (Table 8). In Baja California, the major threats to amphibians are wetland habitat loss and the presence of exotic species. If regional specific criteria were considered in future EVS evaluations, vulnerability values for amphibians in this region likely would be higher and correspond more closely with those from other parts of Mexico.

Relative Herpetofaunal Priority

Johnson et al. (2015) introduced the concept of Relative Herpetofaunal Priority (RHP) as a simple means for measuring the relative importance of the herpetofaunal species in any geographic segment (e.g., state or physiographic region). Ascertaining the RHP involves the employment of two methods: (1) calculating the absolute number of state, country, or regional endemic species as they relate to the entire regional herpetofauna, and (2) calculating the absolute number of high EVS category species in the entire regional herpetofauna. The pertinent data for these two methods are shown in Tables 18 and 19.

Based on the relative number of peninsular endemics (Table 18), the 1<sup>st</sup> rank is held by the GIR with 50 peninsular endemics from a total of 84 species (59.5%). The remaining ranks are as follows: 2<sup>nd</sup> is ATR (26 of 65

species, 40.0%); 3<sup>rd</sup> is CGCR (24 of 62 species, 38.7%); 4<sup>th</sup> is SLLR (21 of 41 species, 51.2%); 5<sup>th</sup> (held by two regions) is MR (18 of 51 species, 35.3%) and VR (18 of 64 species, 28.1%); 6<sup>th</sup> is PIR (15 of 47 species, 31.9%); 7<sup>th</sup> is CR (eight of 60 species, 13.3%); 8<sup>th</sup> is LCVR (five of 68 species, 7.4%); and 9<sup>th</sup> is BCCFR (0 of 27 species, 0.0%).

Clearly, the highest herpetofaunal priority is associated with the Gulf Islands Region. This region consists of all the islands lying off the Baja California Peninsula and within the Gulf of California, excluding those more closely associated with the state of Sonora on the eastern side of the Gulf. Collectively, these islands harbor the largest number of species found in any of the geographic regions of Baja California. The number of species is 84, which is 48.8% of the total number (172) known from the entire peninsula and its adjacent islands. The herpetofauna of these islands is only one of two regional herpetofaunas in which the number of peninsular endemics exceeds that of the non-endemics. The other such region is the SLLR, in which the number of peninsular endemics (21) is greater than the number of non-endemics (18). In the Gulf region, the number of peninsular endemics is 1.6 times that of the non-endemics (50 vs. 32). The 50 peninsular endemics in the Gulf region include species that occupy from one to nine of the 10 recognized regions in the peninsula, as follows:

**Table 19.** Number of herpetofaunal species in the three EVS categories (low, medium, and high) among the 10 geographic regions of the Baja California Peninsula, Mexico. Rank determined by the relative number of high EVS species. Non-native and marine species are excluded.

Geographic region	Low	Medium	High	Total	Rank order
CR	19	29	5	53	9
LCVR	27	26	6	59	8
BCCFR	9	14	4	27	10
VR	20	28	10	58	5
CGCR	16	23	15	54	3
MR	15	21	9	45	7
ATR	15	22	16	53	2
SLLR	11	15	13	39	4
PIR	14	17	10	41	6
GIR	14	17	45	76	1

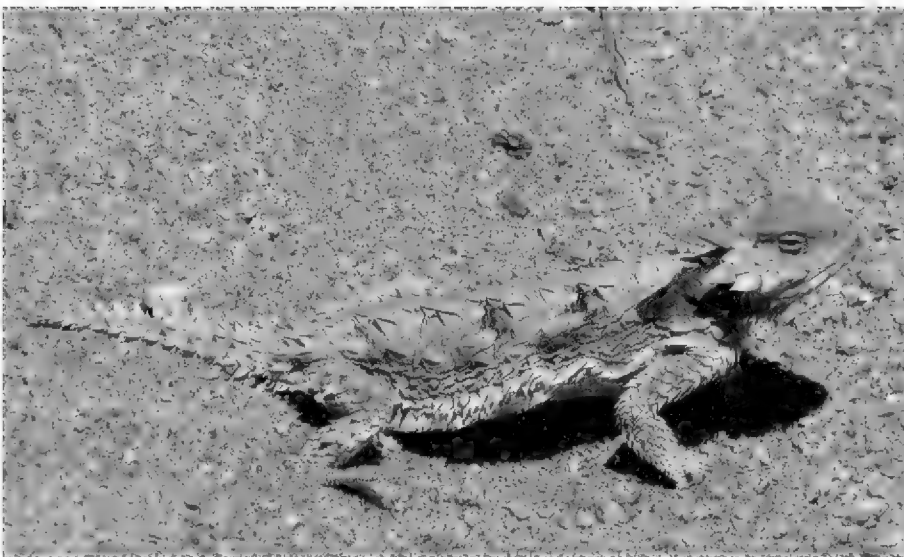




**No. 17.** *Petrosaurus repens* (Van Denburgh, 1895). The Short-nosed Rock Lizard ranges from Mesa San Carlos near the middle of Baja California southward to Arroyo Seco in the Isthmus of La Paz. This individual came from San Miguel Comondú, Baja California Sur. In this study its EVS was calculated as 14, placing it at the lower limit of the high vulnerability category. The IUCN determined its conservation status as Least Concern (LC), and it is not listed by SEMARNAT. *Photo by Jorge H. Valdez-Villavicencio.*



**No. 18.** *Petrosaurus thalassinus* (Cope, 1863). The San Lucan Banded Rock Lizard “is restricted to the Cape Region of Baja California, where it occurs in at least four disjunct populations: one in the Sierra La Laguna and contiguous ranges, another in the Sierra La Trinidad, and one each on the Gulf islands of Espíritu Santo and Partida Sur...” (Grismer 2002: 149). This individual was located at Sierra Las Cacachilas, Baja California Sur, in the municipality of La Paz. In this study its EVS was assessed as 17, placing it in the middle of the high vulnerability category. The IUCN evaluated its conservation status as Least Concern (LC), and SEMARNAT determined it to be a species of Special Protection (Pr). *Photo by Alan Harper.*



**No. 19.** *Phrynosoma blainvillii* Gray, 1839. Blainville's Horned Lizard ranges “west of the Sierra Nevada crest from Shasta County, California, south through all of southern California west of the Mojave and Sonoran deserts” (Grismer 2002: 151) and the extreme northwestern portion of Baja California. This individual was found on the road to Sierra Juárez, Baja California, in the municipality of Ensenada. In this study its EVS was calculated as 12, placing it in the middle of the medium vulnerability category. The IUCN evaluated its conservation status as Least Concern (LC), and it is not listed by SEMARNAT. *Photo by Jorge H. Valdez-Villavicencio.*



**No. 20.** *Phrynosoma coronatum* (Blainville, 1835). The Coast Horned Lizard ranges across the Cape Region of Baja California Sur and across the Magdalena Plain to the southern edge of the Vizcaíno Desert (Leaché et al. 2009). This individual was found in the Sierra Las Cacachilas, Baja California Sur, in the municipality of La Paz. In this study its EVS was assessed as 12, placing it in the upper portion of the medium vulnerability category. The IUCN judged its conservation status as Least Concern (LC), and it is not listed by SEMARNAT. *Photo by Jorge H. Valdez-Villavicencio.*

one (38 species, 76.0%); three (two species, 4.0%); four (two species, 4.0%); five (three species, 6.0%); seven (one species, 2.0%); eight (three species, 6.0%); and nine (one species, 2.0%).

Based on the relative number of high vulnerability species (Table 19), the 1<sup>st</sup> rank is held by the GIR (45 of 76 species, 59.2%), the same rank as for the relative number of country endemics (see above). The rankings are the same for seven of the 10 regions. The high vulnerability ranks for species in the remaining seven regions are as follows: ATR (2<sup>nd</sup>, 16 of 53 species; 30.2%); CGCR (3<sup>rd</sup>, 15 of 54 species; 27.8%); SLLR (4<sup>th</sup>, 13 of 39 species; 33.3%); VR (5<sup>th</sup>, 10 of 58 species; 17.2%); PIR (6<sup>th</sup>, 10 of 41 species; 24.4%); MR (7<sup>th</sup>, nine of 45 species; 20.0%); LCVR (8<sup>th</sup>, six of 59 species; 10.2%); CR (9<sup>th</sup>, five of 53 species; 9.4%); and BCCFR (10<sup>th</sup>, four of 27 species; 14.8%).

Based on the relative numbers of peninsular endemic and high vulnerability species, the 1<sup>st</sup> rank is held by the GIR, the Gulf Islands Region, in which there are 50 peninsular endemics and 45 high vulnerability species. The peninsular endemics include 33 lizards and 17 snakes. These species are indicated with a double asterisk (see Table 4). The GIR also supports 45 high vulnerability species, which are listed below (with the EVS score in parentheses):

*Crotaphytus insularis*\*\* (16)  
*Coleonyx gypsicolus*\*\* (16)  
*Ctenosaura hemilopha*\*\* (16)  
*Dipsosaurus catalinensis*\*\* (17)  
*Sauromalus hispidus*\*\* (14)  
*Sauromalus klauberi*\*\* (17)  
*Sauromalus slevini*\*\* (16)  
*Petrosaurus repens*\*\* (14)  
*Petrosaurus slevini*\*\* (16)  
*Petrosaurus thalassinus*\*\* (17)  
*Sceloporus angustus*\*\* (16)  
*Sceloporus grandaevus*\*\* (17)  
*Sceloporus hunsakeri*\*\* (14)  
*Sceloporus lineatulus*\*\* (17)  
*Uta encantadae*\*\* (17)  
*Uta lowei*\*\* (17)  
*Uta squamata*\*\* (17)  
*Uta tumidarostra*\*\* (17)  
*Phyllodactylus bugastrolepis*\*\* (17)  
*Phyllodactylus partidus*\*\* (16)  
*Phyllodactylus unctus*\*\* (15)  
*Aspidoscelis canus*\*\* (17)  
*Aspidoscelis carmenensis*\*\* (17)  
*Aspidoscelis catalinensis*\*\* (17)  
*Aspidoscelis celeripes*\*\* (16)  
*Aspidoscelis ceralbensis*\*\* (17)  
*Aspidoscelis danheimae*\*\* (17)  
*Aspidoscelis espiritensis*\*\* (16)  
*Aspidoscelis franciscensis*\*\* (17)  
*Aspidoscelis maximus*\*\* (14)

*Aspidoscelis pictus*\*\* (17)  
*Lampropeltis catalinensis*\*\* (18)  
*Masticophis barbouri*\*\* (17)  
*Rhinocheilus etheridgei*\*\* (17)  
*Sonora punctatissima*\*\* (15)  
*Sonora savagei*\*\* (16)  
*Hypsiglena catalinae*\*\* (16)  
*Hypsiglena gularis*\*\* (16)  
*Hypsiglena marcosensis*\*\* (16)  
*Crotalus angelensis*\*\* (18)  
*Crotalus catalinensis*\*\* (19)  
*Crotalus lorenzoensis*\*\* (19)  
*Crotalus mitchellii* (15)  
*Crotalus polisi*\*\* (19)  
*Crotalus thalassoporus*\*\* (19)

All but one of these 45 species are peninsular endemics, and one is an MXUS species. As a group, their EVS values range from 14 to 19.

The 2<sup>nd</sup> rank, with respect to high vulnerability species, is held by the ATR, the Arid Tropical Region, which includes the following 16 high vulnerability species:

*Elgaria paucicarinata*\*\* (14)  
*Elgaria velazquezi*\*\* (15)  
*Bipes biporus*\*\* (19)  
*Ctenosaura hemilopha*\*\* (16)  
*Petrosaurus repens*\*\* (14)  
*Petrosaurus thalassinus*\*\* (17)  
*Sceloporus hunsakeri*\*\* (14)  
*Phyllodactylus unctus*\*\* (15)  
*Phyllodactylus xanti*\*\* (15)  
*Aspidoscelis maximus*\*\* (14)  
*Masticophis aurigulus*\*\* (15)  
*Sonora straminea*\*\* (15)  
*Rena boettgeri*\*\* (14)  
*Crotalus mitchellii*\*\* (15)  
*Trachemys nebulosa*\*\* (15)  
*Gopherus morafkai* (15)

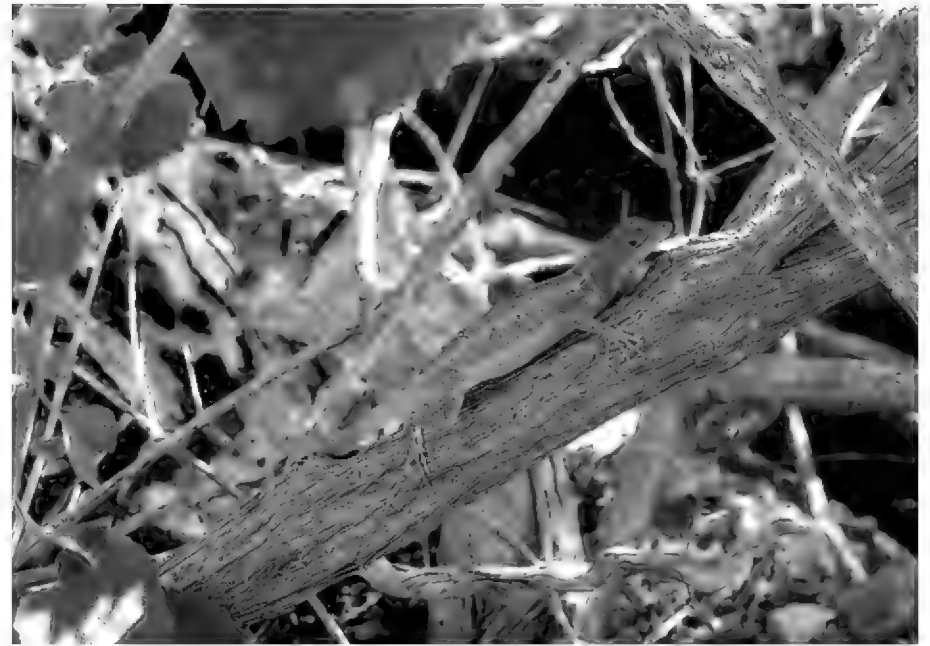
All of these species are peninsular endemics except for one MXUS species. As a group, their EVS values range from 14 to 19.

The 3<sup>rd</sup> rank is held by the CGCR, the Central Gulf Coast Region, which includes the following 15 species:

*Elgaria paucicarinata*\*\* (14)  
*Elgaria velazquezi*\*\* (15)  
*Bipes biporus*\*\* (19)  
*Ctenosaura hemilopha*\*\* (16)  
*Petrosaurus repens*\*\* (14)  
*Petrosaurus thalassinus*\*\* (17)  
*Sceloporus hunsakeri*\*\* (14)  
*Phyllodactylus unctus*\*\* (15)  
*Phyllodactylus xanti*\*\* (15)  
*Aspidoscelis maximus*\*\* (14)  
*Masticophis aurigulus*\*\* (15)



**No. 21.** *Sceloporus angustus* (Dickerson, 1919). The Isla Santa Cruz Spiny Lizard “is known only from Islas San Diego and Santa Cruz in the Gulf of California” (Grismer 2002: 158). This individual was found on Isla Santa Cruz, Gulf of California, in the municipality of Loreto. In this study its EVS is indicated as 16, placing it in the middle portion of the high vulnerability category. The IUCN judged its conservation status as Least Concern (LC), and SEMARNAT indicated it as Threatened (A). *Photo by Alan Harper.*



**No. 22.** *Sceloporus grandaevus* (female). The Isla Cerralvo Spiny Lizard “is endemic to Isla Cerralvo in the Gulf of California in the municipality of La Paz” (Grismer 2002: 159). In this study its EVS was calculated as 17, placing in the middle portion of the high vulnerability category. The IUCN determined its conservation status as Least Concern (LC), and SEMARNAT listed it as Threatened (A). *Photo by Jorge H. Valdez-Villavicencio.*



**No. 23.** *Sceloporus grandaevus* (male). This individual was from Isla Cerralvo, Baja California Sur. Please see the legend for No. 22 for information on its distribution and conservation status. *Photo by Tim Warfel.*



**No. 24.** *Sceloporus licki* Van Denburgh, 1895. The Cape Spiny Lizard “ranges along the mountainous foothill areas of the Cape Region from Rancho Ancón south to near La Soledad in the Sierra La Laguna...” (Grismer 2002: 173). This individual was found at Cañón San Dionisio, Sierra La Laguna, Baja California Sur, in the municipality of Los Cabos. Its EVS was determined as 13, placing it at the upper limit of the medium vulnerability category. The IUCN evaluated its conservation status as Least Concern (LC), and SEMARNAT determined it to be a species of Special Protection (Pr). *Photo by Jorge H. Valdez-Villavicencio.*



## The herpetofauna of the Baja California Peninsula

*Sonora straminea*\*\* (15)  
*Rena boettgeri*\*\* (14)  
*Crotalus mitchellii*\*\* (15)  
*Trachemys nebulosa*\*\* (15)  
*Gopherus morafkai* (15)

Of these 15 species, 14 (93.3%) are peninsular endemics, and one is a non-endemic. As a group, their EVS values range from 14 to 19.

The 4<sup>th</sup> rank is held by the SLLR, the Sierra La Laguna Region, which includes the following 13 high vulnerability species:

*Elgaria paucicarinata*\*\* (14)  
*Ctenosaura hemilopha*\*\* (16)  
*Petrosaurus thalassinus*\*\* (17)  
*Sceloporus hunsakeri*\*\* (14)  
*Phyllodactylus unctus*\*\* (15)  
*Phyllodactylus xanti*\*\* (15)  
*Aspidoscelis maximum*\*\* (14)  
*Xantusia gilberti*\*\* (15)  
*Masticophis aurigulus*\*\* (15)  
*Sonora straminea*\*\* (15)  
*Rena boettgeri*\*\* (14)  
*Crotalus mitchellii*\*\* (15)  
*Trachemys nebulosa*\*\* (15)

All of these species are peninsular endemics. As a group, their EVS values range from 14 to 17.

The 5<sup>th</sup> rank is held by the VR, the Vizcaíno Region, which includes the following 10 high vulnerability species:

*Elgaria velazquezi*\*\* (15)  
*Anniella geronimensis*\*\* (14)  
*Bipes biporus*\*\* (19)  
*Petrosaurus repens*\*\* (14)  
*Phrynosoma cerroense*\*\* (14)  
*Urosaurus lahtelai*\*\* (16)  
*Aspidoscelis labialis*\*\* (15)  
*Arizona pacata*\*\* (14)  
*Crotalus mitchelli*\*\* (15)  
*Trachemys nebulosa*\*\* (15)

Of these 10 species, all are peninsular endemics (76.9%), and three are non-endemics. As a group, their EVS values range from 14 to 19.

The 6<sup>th</sup> rank is held by the PIR, the Pacific Islands Regions, which includes the following 10 high vulnerability species:

*Aneides lugubris* (14)  
*Batrachoseps major* (14)  
*Elgaria cedrosensis*\*\* (16)

*Elgaria nana*\*\* (16)  
*Anniella geronimensis*\*\* (14)  
*Bipes biporus*\*\* (19)  
*Phrynosoma cerroense*\*\* (14)  
*Lampropeltis herrerae*\*\* (20)  
*Pituophis insulanus*\*\* (17)  
*Crotalus mitchellii*\*\* (15)

Of the 10 species in the PIR, eight are peninsular endemics and two are non-endemics. As a group, their EVS values range from 14 to 20.

The 7<sup>th</sup> rank is held by the MR, the Magdalena Region, which includes the following nine high vulnerability species:

*Elgaria velazquezi*\*\* (14)  
*Bipes biporus*\*\* (14)  
*Ctenosaura hemilopha*\*\* (18)  
*Petrosaurus repens*\*\* (14)  
*Phrynosoma cerroense*\*\* (16)  
*Xantusia sherbrookei*\*\* (16)  
*Arizona pacata*\*\* (14)  
*Crotalus mitchellii*\*\* (15)  
*Trachemys nebulosa*\*\* (18)

All nine of these species are peninsular endemics. As a group, their EVS values range from 14 to 18.

The 8<sup>th</sup> rank is held by the LCVR, the Lower California Valley Region, which includes the following six high vulnerability species:

*Crotaphytus grismeri*\*\* (16)  
*Phrynosoma mcallii* (15)  
*Uma notata* (15)  
*Urosaurus graciosus* (15)  
*Sonora annulata* (14)  
*Crotalus cerastes* (16)

Of these six species, five are non-endemics and one is a peninsular endemic. As a group, their EVS values range from 14 to 16.

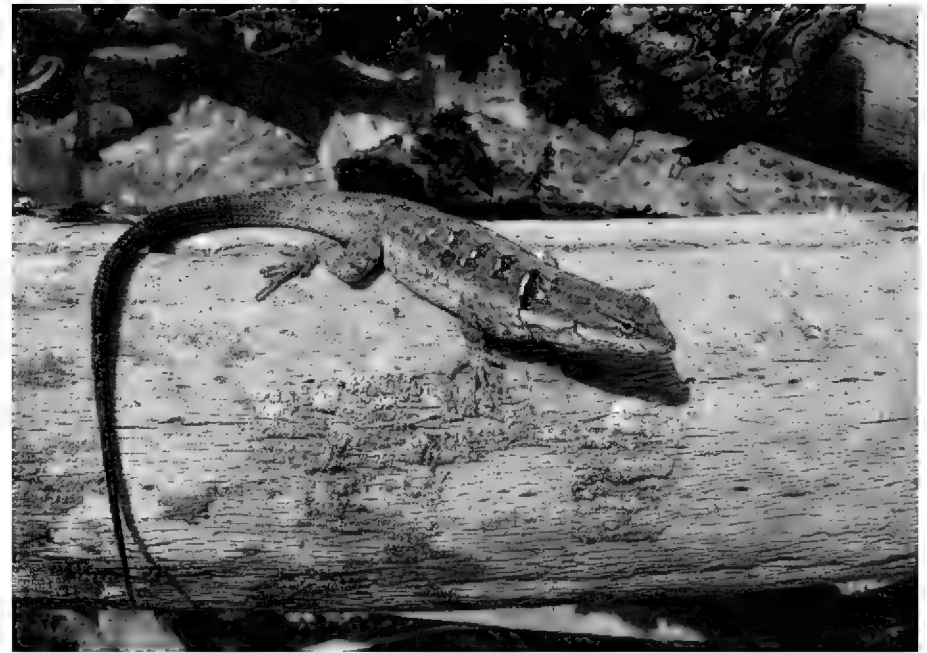
The 9<sup>th</sup> rank is held by the CR, the California Region, which includes the following five high vulnerability species:

*Aneides lugubris* (14)  
*Batrachoseps major* (14)  
*Anniella geronimensis*\*\* (14)  
*Phrynosoma cerroense*\*\* (14)  
*Aspidoscelis labialis*\*\* (15)

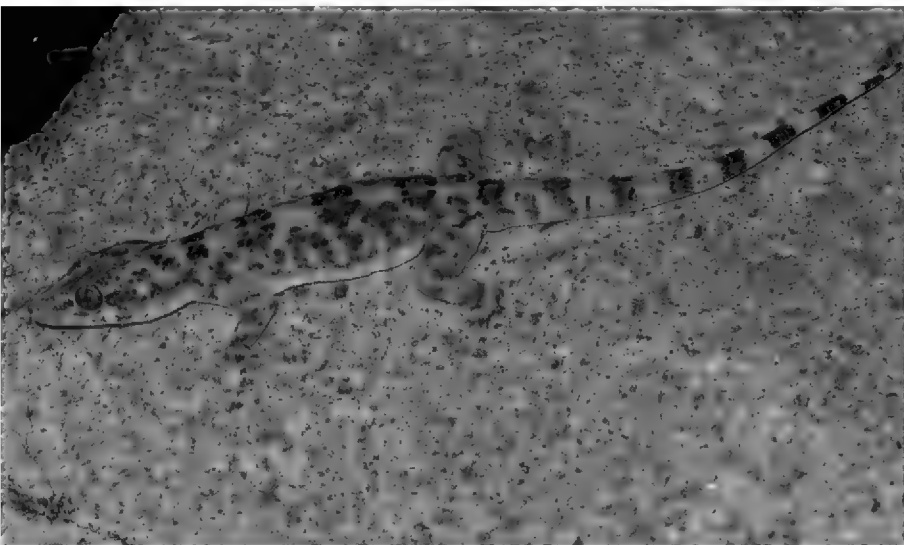
Three of these species are peninsular endemics, and the other two are non-endemics. As a group, their EVS values range from 14 to 15.



**No. 25.** *Sceloporus vandenburgianus* Cope, 1896. The Southern Sagebrush Lizard occurs “from the Coast Ranges in Los Angeles County, California, south to southern San Diego County. A disjunct population occurs in the Sierra Juarez and Sierra San Pedro Mártir, Baja California, Mexico...” (Grismer 2002: 174). This individual came from La Tasajera, Sierra San Pedro Mártir, in the municipality of Ensenada. In this study its EVS is noted as 14, placing it at the lower limit of the high vulnerability category. The IUCN judged its conservation status as Least Concern (LC), and SEMARNAT assessed it as a species of Special Protection (Pr). *Photo by Jorge H. Valdez-Villavicencio.*



**No. 26.** *Urosaurus nigricaudus* (Cope, 1864). The Black-tailed Brush Lizard “ranges along the eastern side of the Peninsular Ranges from San Diego County, California, south to the Cape Region of Baja California Sur” (Grismer 2002: 180). This individual was found in the Cañón San Dionisio, Sierra La Laguna, Baja California Sur, in the municipality of Los Cabos. In this study its EVS was estimated as 7, placing it in the upper portion of the low vulnerability category. The IUCN judged its conservation status as Least Concern (LC), and SEMARNAT listed it as Threatened (A). *Photo by Jorge H. Valdez-Villavicencio.*



**No. 27.** *Phyllodactylus unctus* (Cope, 1863). The San Lucan Leaf-toed Gecko “on the peninsula...is restricted to the Cape Region. In the Gulf of California, it has been reported from Islas Partida Sur, Espíritu Santo, Ballena, Gallo, Gallina, and Cerralvo...” Grismer 2002: 209). This individual was found in the Sierra Las Cacachilas, Baja California Sur, in the municipality of La Paz. In this study its EVS is indicated as 15, placing it in the lower portion of the high vulnerability category. The IUCN judged its conservation status as Near Threatened (NT), and SEMARNAT assessed this gecko as a species of Special Protection (Pr). *Photo by Jorge H. Valdez-Villavicencio.*



**No. 28.** *Plestiodon lagunensis* Van Denburgh, 1895. The San Lucan Skink “has a disjunct distribution throughout southern Baja California...In the Cape Region, it is restricted to the Sierra La Laguna and associated eastern foothills. North of the Cape Region, it is known from four localities: the vicinity of the Comondús; Santa Águeda, approximately 150 km to the north...; northern Sierra Guadalupe; and San Francisco de la Sierra...” (Grismer 2002: 237–238). This individual came from La Purisima, Baja California Sur, in the municipality of Comondú. In this study its EVS was judged as 13, placing it at the upper limit of the medium vulnerability category. The IUCN assessed its conservation status as Least Concern (LC), and SEMARNAT indicated it as a species of Special Protection (Pr). *Photo by Jorge H. Valdez-Villavicencio.*

The 10<sup>th</sup> rank is held by the BCCFR, the Baja California Coniferous Forest Region, which includes the following four high vulnerability species:

*Batrachoseps major* (14)  
*Sceloporus vandenburgianus* (14)  
*Lampropeltis multifasciata* (14)  
*Thamnophis elegans* (14)

All four of these species are non-endemics, and they all have EVS values of 14.

### Natural Protected Areas in the Baja California Peninsula and its Adjacent Islands

#### Natural Protected Areas

In Mexico, natural protected areas (ANPs, from the Spanish acronym for “Áreas Naturales Protegidas” or NPAs for “Natural Protected Areas” in English) are those established to preserve natural environments among the different landscapes of the country for the conservation of endemic and endangered species, as well as for maintaining their genetic diversity and for promoting sustainable use and scientific research.

The Baja California Peninsula contains 30 NPAs, which are divided into the following six categories: National Parks, Biosphere Reserves, Flora and Fauna Protection Areas, State Parks, State Reserves, and Voluntarily Designated Conservation Areas (Áreas Designadas Voluntariamente a la Conservación, or ADVC for the Spanish acronym). Of these, 17 are administrated at the federal level and two at the state level, while the remaining 11 are private (Table 20). Twenty-five of the NPAs are terrestrial and five are marine reserves. The NPAs were created between the years 1947 and 2022, with Sierra San Pedro Mártir National Park being the first reserve established in the Baja California Peninsula.

Terrestrial NPAs cover slightly more than 73,000 km<sup>2</sup>, which corresponds to 49.5% of the total area of the Baja California Peninsula and its associated islands. The marine protected areas cover about 17,268 km<sup>2</sup> of marine habitat. Two NPAs are the largest in Mexico. The El Vizcaíno Biosphere Reserve in Baja California Sur is the largest in the country, followed by the Área de Protección de Flora y Fauna Valle de los Cirios in the state of Baja California, and each of these NPAs covers more than 20,000 km<sup>2</sup> of areal extension. Together they cover 56% of the total area designed for the protection of biodiversity and natural resources in the peninsula. In addition to the considerable protected land area represented by the NPAs, these areas are distributed in all 10 of the physiographic regions throughout the peninsula (Table 20), and thus represent all of its ecosystems.

Eleven natural protected areas are privately owned, primarily in such large areas as Valle de los Cirios and El Vizcaíno, which contain several towns and

ranches. Although conservation objectives often are not compatible with the activities of the landowners (e.g., agriculture and cattle ranching), the federal governmental institutions promote agreements with them on the proper use of their resources, as well as in environmental education to properly carry out the management programs. Some of the Pacific Islands are inhabited, such as Cedros, Natividad, Guadalupe, Magdalena, and Santa Margarita, but the users do not own the land; and in most cases their use is primarily dedicated to fishing activities. For this reason, several NGOs collaborate with the staff of the NPAs to carry out adequate management programs and environmental education for the proper management of the resources, and also to avoid the introduction of non-native species into the islands. In areas such as the Sierra San Pedro Mártir, however, relationships with the landowners are complicated, as they use the core areas of the NPAs for cattle ranching.

Regarding herpetofaunal inventories, only six of the 23 terrestrial areas (26.1%) have conducted them. This situation highlights the general lack of sufficient herpetological surveys in these areas. In all seven of the marine reserves, five species of turtles are known to inhabit these areas (*Chelonia mydas*, *Caretta caretta*, *Lepidochelys olivacea*, *Eretmochelys imbricata*, and *Dermochelys coriacea*), in addition to the Yellow-bellied Sea Snake (*Hydrophis platurus*). Only one of these marine areas, Complejo Lagunar Ojo de Liebre, is located in the Pacific Ocean, and the remainder are in the Gulf of California.

#### Effectiveness of the Natural Protected Areas in the Baja California Peninsula and Its Adjacent Islands

The available information on the distribution of the herpetofaunal species known to occur within the NPAs in the Baja California Peninsula and its adjacent islands are shown in Table 21, and the results are summarized in Table 22. The data in these tables indicate that 157 (91.3%) of the 172 total species known from this region of Mexico have been recorded in one to 25 of the 30 NPAs. Thus, 15 species recorded from the Baja California Peninsula and its adjacent islands have not been recorded from any of the NPAs, and therefore are not included in Table 21. These 15 species are: *Anaxyrus woodhousii*, *Incilius alvarius*, *Smilisca baudinii*\*\*\*, *Xenopus laevis*\*\*\*, *Lithobates berlandieri*\*\*\*, *L. forreri*\*\*\*, *L. yavapaiensis*, *Crotaphytus grismeri*\*\*, *Gehyra mutilata*\*\*\*, *Uma notata*, *Xantusia sherbrookei*\*\*, *Thamnophis marcianus*, *Kinosternon integrum*\*\*\*, *Gopherus morafkai*, and *Apalone spinifera*\*\*\*. Seven of these 15 species (indicated by triple asterisks) are non-native to the Baja California Peninsula and its adjacent islands, and thus are not desirable for inclusion in any of the NPAs. Therefore, only eight species (the two country endemics indicated by double asterisks and the six non-endemics) should





**No. 29.** *Aspidoscelis catalinensis*. The Isla Santa Catalina Whiptail “is endemic to Isla Santa Catalina, in the Gulf of California, Baja California Sur” (Grismer 2002: 230). In this study its EVS was estimated as 17, placing it in the middle portion of the high vulnerability category. The IUCN judged its conservation status as Vulnerable (VU), and SEMARNAT assessed it as a species of Special Protection (Pr). *Photo by Tim Warfel.*



**No. 30.** *Aspidoscelis hyperythrus* (Cope, 1863). The Orange-throated Whiptail occurs “from Orange and San Bernardino counties of southern California south to Cabo San Lucas...” (Grismer 2002: 212). This individual came from Rancho Meling, Sierra San Pedro Mártir, Baja California, in the municipality of San Quintín. In this study its EVS was determined as 10, placing it at the lower limit of the medium vulnerability category. The IUCN evaluated its conservation status as Least Concern (LC), and SEMARNAT judged it as Threatened (A). *Photo by Jorge H. Valdez-Villavicencio.*



**No. 31.** *Aspidoscelis labialis* (Stejneger, 1890). The Baja California Whiptail “ranges along a narrow strip of the Pacific coast, from Punta San José just south of Ensenada south to at least 6 km southeast of Guerrero Negro. It generally extends no more than 16 km inland...in the northern Vizcaíno Desert and even less so farther north” (Grismer 2002: 220). This individual was found at Guerrero Negro, Baja California Sur, in the municipality of Mulegé. In this study its EVS was estimated as 15, placing it in the lower portion of the high vulnerability category. The IUCN judged its conservation status as Vulnerable (VU), and SEMARNAT listed it as a species of Special Protection (Pr). *Photo by Jorge H. Valdez-Villavicencio.*



**No. 32.** *Aspidoscelis maximus* (Cope, 1863). The Cape Region Whiptail is distributed in the Cape Region from Bahía La Paz to Cabo San Lucas, including the Gulf islands of Partida Sur and Espíritu Santo (Grismer 2002). This individual was located at Sierra Las Cacachilas, in the municipality of La Paz. In this study its EVS was calculated as 14, placing it at the lower limit of the high vulnerability category. The IUCN has not assessed the conservation status of this species, but it was evaluated by SEMARNAT as a species of Special Protection (Pr). *Photo by Alan Harper.*

**Table 20.** Characteristics of the Natural Protected Areas in the Baja California Peninsula, Mexico. Abbreviations in the Facilities available column are as follows: A = administrative services; R = park guards; S = system of pathways; and V = facilities for visitors.

Name	Category	Date of decree	Area (ha)	Municipalities	Jurisdiction	Physiographic regions	Facilities available	Occupied by landowners	Herpetofaunal survey completed	Management plan available
Constitución de 1857	Parque Nacional	27 Apr 1962	5,009.5	Ensenada	Federal	Baja California Coniferous Forest	A, R, S, V	Yes	No	Yes
Alto Golfo de California y Delta del Río Colorado	Reserva de la Biósfera	10 Jun 1993	1,340	Mexicali, San Felipe	Federal	Lower Colorado Valley	A, R, S	Yes	No	Yes
Arroyo San Miguel	Parque Estatal	17 Sep 2021	67	Ensenada	State	California	None	Yes	No	No
Sierra San Pedro Mártir	Parque Nacional	26 Apr 1947	72,910.7	Ensenada	Federal	Baja California Coniferous Forest	A, R, S, V	Yes	Yes	Yes
Los Montes de San Pedro I, II, III	ADVC	31 May 2019	4,502	Ensenada	Private	Baja California Coniferous Forest	A	Yes	No	Yes
Reserva Natural San Quintín	ADVC	22 Jan 2021	201	San Quintín	State	California	A	No	No	Yes
Reserva Natural Punta Mazo	ADVC	20 Oct 2014	832.5	San Quintín	Private	California	R, S, V	No	Yes <sup>A</sup>	Yes
Reserva Natural Monte Ceniza	ADVC	18 Apr 2017	803.4	San Quintín	Private	California	R, S	No	No	Yes
Reserva Natural Valle Tranquillo	ADVC	24 Oct 2013	3,691.2	San Quintín	Private	California, Vizcaíno	R, S	No	No	Yes
Valle de los Cirios	Área de Protección de Flora y Fauna	2 Jun 1980	2,521,987.6	San Quintín, San Felipe	Federal	Vizcaíno	A, R, S	Yes	No	Yes
Costa Salvaje Wildlands I, II, III, IV	ADVC	2013, 2014, 2016, 2019	17,532.8	San Quintín	Private	Vizcaíno	A	No	No	No
Islas del Golfo de California	Área de Protección de Flora y Fauna	2 Aug 1978	374,553.6	Mexicali, San Felipe, San Quintín, Mulegé, Loreto, La Paz	Federal	Gulf Islands	A	No**	Yes	Yes
Isla Guadalupe	Reserva de la Biósfera	25 Apr 2005	476,971.2	Ensenada	Federal	Pacific Islands	A, S, V	Yes***	Yes*	Yes
Islas del Pacífico de la Península de Baja California	Reserva de la Biósfera	7 Dec 2016	1,161,223	Tijuana, Ensenada, San Quintín, Mulegé, Comondú	Federal	Pacific Islands	A	No****	Yes	No
Zona Marina del Archipiélago de San Lorenzo	Parque Nacional	25 Apr 2005	58,442.8	San Quintín	Federal	Gulf Islands	A	No	No	Yes

**Table 20 (continued).** Characteristics of the Natural Protected Areas in the Baja California Peninsula, Mexico. Abbreviations in the Facilities available facilities column are as follows: A = administrative services; R = park guards; S = system of pathways; and V = facilities for visitors.

Name	Category	Date of decree	Area (ha)	Municipalities	Jurisdiction	Physiographic regions	Facilities available	Occupied by landowners	Herpetofaunal survey completed	Management plan available
Zona Marina Bahía de los Angeles, Canales de Ballenas y Salsipuedes	Reserva de la Biósfera	5 Jun 2007	387,956.9	San Quintín	Federal	Gulf Islands	A	No	No	Yes
Complejo Lagunar Ojo de Liebre	Reserva de la Biósfera	28 Mar 1980	79,329	San Quintín, Mulegé	Federal	Vizcaíno	A, R, S	No	No	Yes
El Vizcaíno	Reserva de la Biósfera	30 Nov 1988	2,546,790.2	Mulegé	Federal	Vizcaíno	A, R, S	Yes	Yes	Yes
Servidumbre Ecológica Rancho San Cistóbal-Majibén	ADCV	3 May 2012	538.5	Mulegé	Private	Vizcaíno	A, S	Yes	No	No
Bahía de Loreto	Parque Nacional	19 Jul 1996	206,580.7	Loreto	Federal	Gulf Islands	A	No	No	Yes
Reserva Ecológica Llanos de Magdalena I, II	ADCV	2013, 2014	1,067	Comondú	Private	Magdalena	A, S	No	No	No
Reserva Natural el Portezuelo I, II, III, IV, V	ADCV	2013, 2014, 2019	6,825.1	Loreto, La Paz	Private	Central Gulf Coast	A, S	No	No	No
Santa Martha	ADCV	1 Jun 2016	479	Loreto	Private	Central Gulf Coast	A, S	No	No	No
Zona Marina del Archipiélago de Espíritu Sano	Parque Nacional	10 May 2007	48,654.8	La Paz	Federa;	Central Gulf Coast	A, R	No	No	Yes
Balandra	Área de Protección de Flora y Fauna	30 Nov 2012	2,512.7	La Paz	Federal	Central Gulf Coast	A, S	No	No	Yes
Non-such	ADCV	28 Jul 2022	80	La Paz	Private	Magdalena	A, S	No	No	No
Sierra La Laguna	Reserva de la Biósfera	6 Jun 1994	112,437	La Paz, Los Cabos	Federal	Sierra Laguna	A, R, S	Yes	Yes	Yes
Cabo Pulmo	Parque Nacional	6 Jun 1995	7,111	Los Cabos	Federal	Central Gulf Coast	A, R, V	No	No	Yes
Estero de San José del Cabo	Parque Nacional	10 Jan 1994	512.2	Los Cabos	State	Arid Tropical	A	No	No	Yes
Cabo San Lucas	Área de Protección de Flora y Fauna	29 Nov 1973	3,996	Los Cabos	Federal	Arid Tropical	A	Yes	No	Yes





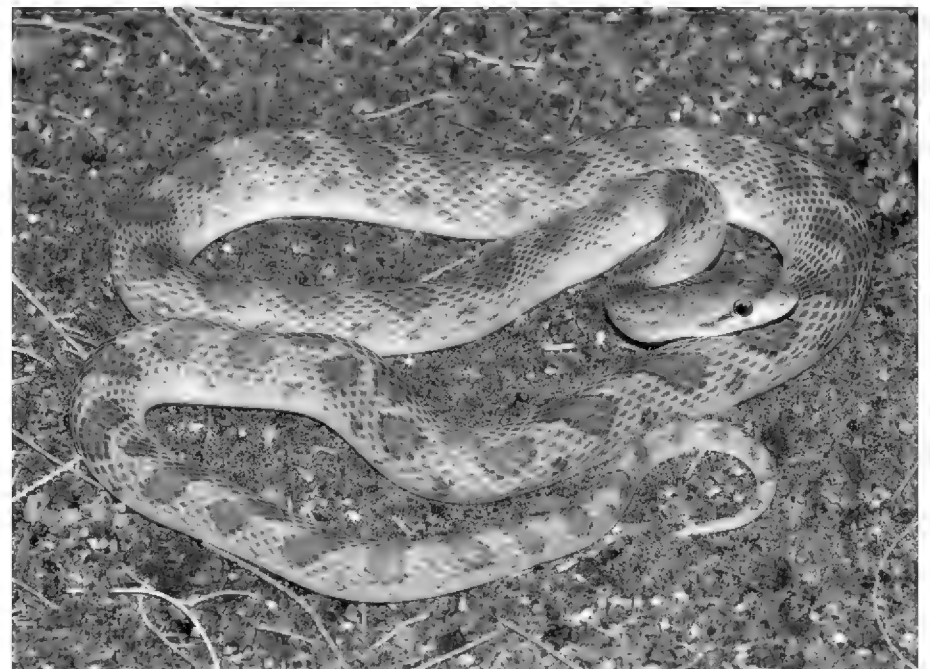
**No. 33.** *Xantusia henshawi* Stejneger, 1893. The Granite Night Lizard “ranges from western Riverside County, California, south into northwestern Baja California, to at least Cañón el Cajón of the Sierra San Pedro Mártir in the east and Valle la Trinidad in the west...” (Grismer 2002: 233). This individual was found at Rancho Meling, Sierra San Pedro Mártir, in the municipality of San Quintín. Its EVS was indicated as 11, placing it in the lower portion of the medium vulnerability category. The IUCN determined its conservation status as Least Concern (LC), but this species is not listed by SEMARNAT. *Photo by Jorge H. Valdez-Villavicencio.*



**No. 34.** *Xantusia wigginsi* Savage, 1952. Wiggins' Night Lizard ranges from southern San Diego County, California southward to northeastern Baja California Sur (<http://californiaherps.com>; accessed 11 December 2022). This individual came from south of Cataviña, Baja California, in the municipality of San Quintín. The species EVS was determined as 11, placing it at the lower portion of the medium vulnerability category. This species is not listed by either the IUCN or SEMARNAT. *Photo by Jorge H. Valdez-Villavicencio.*



**No. 35.** *Lichanura trivirgata* Cope, 1861. The Rosy Boa “ranges widely throughout the Mojave and Sonoran deserts of the southwestern United States and northern Mexico, as well as coastal regions of southern California...In Baja California, *L. trivirgata* occurs in all areas...except for the upper elevations of the northern Peninsular Ranges...and the Sierra La Laguna” (Grismer 2002: 260). This individual was found on Isla Cedros, in the municipality of Ensenada. In this study its EVS was estimated as 10, placing it at the lower limit of the medium vulnerability category. The IUCN judged its conservation status as Least Concern (LC), and SEMARNAT calculated it as Threatened (A). *Photo by Jorge H. Valdez-Villavicencio.*



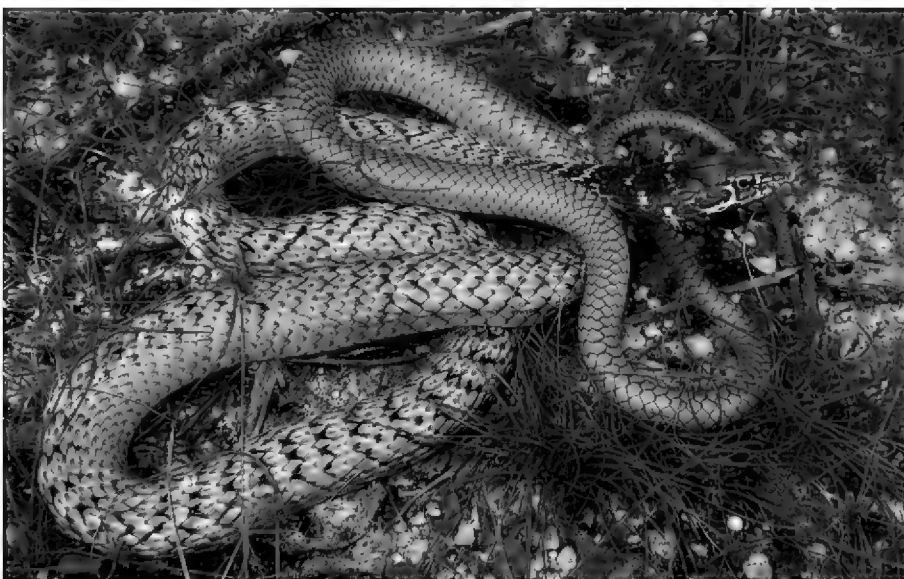
**No. 36.** *Arizona pacata* Klauber, 1946. The Peninsular Glossy Snake “ranges along the Pacific coast of the southern two-thirds of Baja California from at least the turnoff to Bahía de los Ángeles south to 20 km north of La Paz” (Grismer 2002: 265). This individual was found in Guerrero Negro, Baja California Sur, in the municipality of Mulegé. In this study its EVS was determined as 14, placing it at the lower limit of the high vulnerability category. The IUCN assessed its conservation status as Least Concern (LC), but this snake is not listed by SEMARNAT. *Photo by Tim Warfel.*



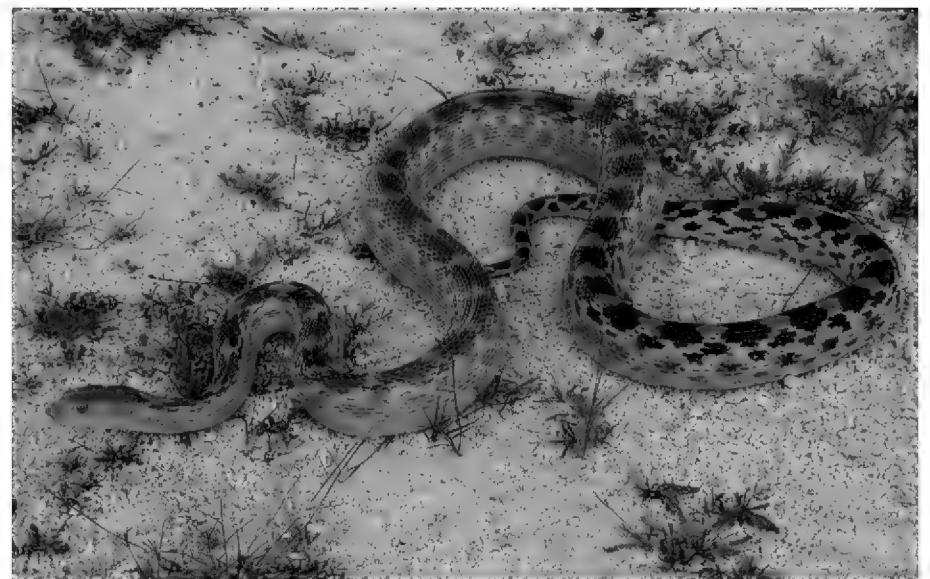
**No. 37.** *Bogertophis rosaliae* (Mocquard, 1899). The Baja California Rat Snake occurs “throughout the rocky slopes of the Peninsular Ranges from Mountain Springs, San Diego County, California, south to Cabo San Lucas...” (Grismer 2002: 266). This individual came from the Sierra Las Cacachilas, Baja California Sur, in the municipality of La Paz. In this study its EVS was estimated as 11, placing it in the medium vulnerability category. The IUCN assessed its conservation status as Least Concern (LC), but this species is not listed by SEMARNAT. *Photo by Jorge H. Valdez-Villavicencio.*



**No. 38.** *Masticophis aurigulus* (Cope, 1861). The Cape Striped Racer “is known only from the Cape Region of Baja California, along the eastern slopes of the Sierra La Laguna...” (Grismer 2002: 286). This individual came from San Bartolo, Baja California Sur, in the municipality of La Paz. In this study its EVS was calculated as 15, placing it in the lower portion of the high vulnerability category. The IUCN assessed its conservation status as Least Concern (LC), and SEMARNAT determined its conservation status as Threatened (A). *Photo by Jorge H. Valdez-Villavicencio.*



**No. 39.** *Masticophis fuliginosus* (Cope, 1895). The Baja California Coachwhip “ranges from extreme southwestern California south to Cabo San Lucas” (Grismer 2002: 290). This individual was encountered in the Sierra Las Cacachilas, Baja California Sur, in the municipality of La Paz. In this study its EVS was estimated as 9, placing it at the upper limit of the low vulnerability category. This species is not listed by either the IUCN or SEMARNAT. *Photo by Jorge H. Valdez-Villavicencio.*



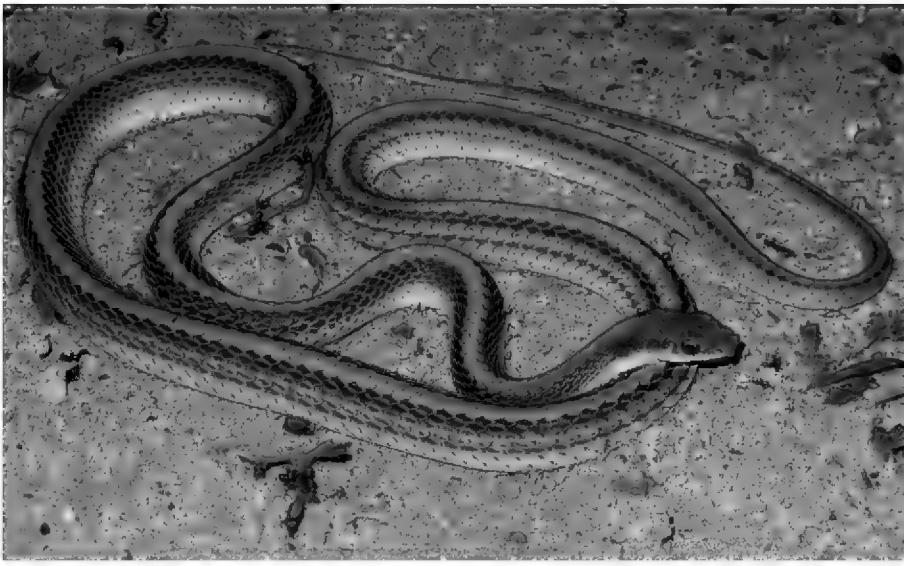
**No. 40.** *Pituophis vertebralis* (Blainville, 1835). The Baja California Gopher Snake “is endemic to Baja California peninsula, ranging continuously throughout cismontane areas from at least 43 km south (by road) of El Rosario south to Cabo San Lucas...” (Grismer 2002: 298). This individual was found in the Sierra Las Cacachilas, Baja California Sur, in the municipality of La Paz. In this study its EVS was determined as 13, placing it at the upper limit of the medium vulnerability category. The IUCN assessed its conservation status as Least Concern (LC), but this snake is not listed by SEMARNAT. *Photo by Jorge H. Valdez-Villavicencio.*

The herpetofauna of the Baja California Peninsula

**Table 21.** Distribution of herpetofaunal species in the Natural Protected Areas of the Baja California Peninsula, Mexico. Abbreviations are as follows: \* = species endemic to Mexico; \*\* = species endemic to Baja California; and \*\*\* = non-native species. The numbers of the Natural Protected Areas signify the following: 1 = Constitución de 1857; 2 = Alto Golfo y Delta del Río Colorado; 3 = Arroyo San Miguel; 4 = Sierra San Pedro Mártir; 5 = Los Montes de San Pedro; 6 = Reserva Natural San Quintín; 7 = Reserva Natural Punta Mazo; 8 = Reserva Natural Monte Ceniza; 9 = Reserva Natural Valle Tranquilo; 10 = Valle de los Cirios; 11 = Costa Salvaje Wildlands; 12 = Islas del Golfo de California; 13 = Isla Guadalupe; 14 = Islas del Pacífico de la Península de Baja California; 15 = Zona Marina del Archipiélago de San Lorenzo; 16 = Zona Marina Bahía de los Ángeles, Canales de Ballenas y Salsipuedes; 17 = Complejo Lagunar Ojo de Liebre; 18 = El Vizcaíno; 19 = Servidumbre Ecológica Rancho San Cristóbal-Majiben; 20 = Bahía de Loreto; 21 = Reserva Ecológica Llanos de Magdalena; 22 = Reserva Natural El Portezuelo; 23 = Santa Martha; 24 = Zona marina del Archipiélago de Espíritu Santo; 25 = Balandra; 26 = Non-Such; 27 = Sierra La Laguna; 28 = Cabo Pulmo; 29 = Estero de San José del Cabo; and 30 = Cabo San Lucas.

Taxon	Natural Protected Areas																													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
AMPHIBIA (14 species)																														
Anura (11 species)																														
Bufonidae (4 species)																														
Anaxyrus boreas	+		+	+	+				+	+																				
Anaxyrus californicus	+			+	+																									
Anaxyrus cognatus		+																												
Anaxyrus punctatus										+	+	+						+	+	+	+	+	+		+	+	+		+	
Hylidae (2 species)																														
Pseudacris cadaverina	+		+	+	+					+																				
Pseudacris hypochondriaca	+		+	+	+				+	+				+				+							+		+		+	
Ranidae (3 species)																														
Lithobates catesbeianus***																		+												
Rana draytonii				+																										
Rana boylei				+																										
Scaphiopodidae (2 species)																														
Scaphiopus couchii		+								+		+						+				+	+		+	+	+			
Spea hammondi	+		+						+																					
Caudata (3 species)																														
Plethodontidae (3 species)																														
Aneides lugubris			+											+																
Batrachoseps major	+		+	+	+									+																
Ensatina eschscholtzii	+			+																										
REPTILIA (143 species)																														
Squamata (135 species)																														
Anguidae (5 species)																														
Elgaria cedrosensis**										+	+			+																
Elgaria multicarinata	+		+	+	+				+	+				+																
Elgaria nana**														+																
Elgaria paucicarinata**																											+		+	
Elgaria velazquezi*																		+				+								
Anniellidae (2 species)																														
Anniella geronimensis**							+							+																
Anniella stebbinsi														+																
Bipedidae (1 species)																														
Bipes biporus**										+				+				+	+		+					+				
Crotaphytidae (4 species)																														
Crotaphytus insularis**												+																		
Crotaphytus vestigium										+								+												
Gambelia copeii**									+	+	+			+				+	+		+					+				
Gambelia wislizenii		+																												
Eublepharidae (3 species)																														
Coleonyx gypsicolus**												+																		
Coleonyx switaki		+								+								+												
Coleonyx variegatus	+	+	+		+	+	+	+	+	+	+	+		+				+	+		+	+	+		+	+	+		+	+
Gekkonidae (2 species)																														





**No. 41.** *Salvadora hexalepis* (Cope, 1866). The Western Patch-nosed Snake is distributed “through much of the American southwest and most of northwestern Mexico. In Baja California, *S. hexalepis* ranges throughout the entire peninsula...except for the upper elevations of the Sierra Juárez and Sierra San Pedro Mártir...It is known from the Pacific islands of San Gerónimo and Todos Santos and from the Gulf islands of Espíritu Santo, San José, and Tiburón” (Grismer 2002: 303). This individual was found in the Sierra Las Cacachilas, Baja California Sur, in the municipality of La Paz. Its EVS was calculated as 9, placing it at the higher limit of the low vulnerability category. The IUCN assessed its conservation status as Least Concern (LC), but this species is not listed by SEMARNAT. *Photo by Jorge H. Valdez-Villavicencio.*



**No. 42.** *Sonora annulata* (Baird, 1859). The Shovel-nosed Snake is distributed “in the Colorado and Sonoran Deserts of Arizona and California in the USA, and in the states of Baja California and Sonora in Mexico” (Cox et al. 2018). “In Baja California, *S. annulata* is restricted to the Lower Colorado Valley Region, extending 34 km south of San Felipe” (Grismer 2002: 271). This individual was located at Restaurant El Michoacán, El Chinero, Baja California in the municipality of Mexicali. The species EVS was calculated as 14, placing it at the lower limit of the high vulnerability category. This snake is not listed by either IUCN or SEMARNAT. *Photo by Tim Warfel.*



**No. 43.** *Sonora fasciata* (Cope, 1892). The Banded Sand Snake is distributed “from the central Baja California Peninsula at least as far north as Las Tres Virgenes to southern Baja California Sur near El Triunfo” (Cox et al. 2018). This individual came from near Loreto, Baja California Sur, in the municipality of Loreto. In this study its EVS was assessed as 12, placing it in the higher portion of the middle vulnerability category. This species is not listed by the IUCN, but SEMARNAT lists it as a species of Special Protection (Pr). *Photo by Jorge H. Valdez-Villavicencio.*

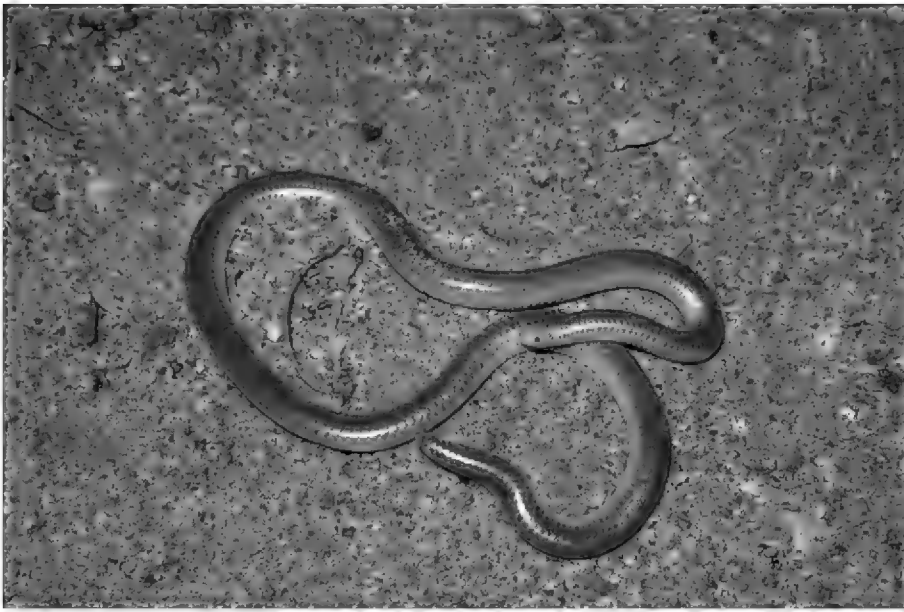


**No. 44.** *Hypsiglena slevini* Tanner, 1943. The Slevin's Night Snake occurs from near Puertecitos in the north (Murray et al. 2015) and “ranges continuously from at least Bahía de los Ángeles in the north to Cabo San Lucas in the south...It is also known from Isla Santa Margarita, of the west coast of Baja California...and from Islas Cerralvo and Danzante in the Gulf of California” (Grismer 2002: 273). This individual came from Sierra la Gata, Baja California Sur, in the municipality of La Paz. In this study its EVS is noted as 11, placing it in the lower portion of the medium vulnerability category. The IUCN assessed its conservation status as Least Concern (LC), but SEMARNAT judged its conservation status as Threatened (A). *Photo by Jorge H. Valdez-Villavicencio.*

The herpetofauna of the Baja California Peninsula

**Table 21 (continued).** Distribution of herpetofaunal species in the Natural Protected Areas of the Baja California Peninsula, Mexico. Abbreviations are as follows: \* = species endemic to Mexico; \*\* = species endemic to Baja California; and \*\*\* = non-native species. The numbers of the Natural Protected Areas signify the following: 1 = Constitución de 1857; 2 = Alto Golfo y Delta del Río Colorado; 3 = Arroyo San Miguel; 4 = Sierra San Pedro Mártir; 5 = Los Montes de San Pedro; 6 = Reserva Natural San Quintín; 7 = Reserva Natural Punta Mazo; 8 = Reserva Natural Monte Ceniza; 9 = Reserva Natural Valle Tranquilo; 10 = Valle de los Cirios; 11 = Costa Salvaje Wildlands; 12 = Islas del Golfo de California; 13 = Isla Guadalupe; 14 = Islas del Pacífico de la Península de Baja California; 15 = Zona Marina del Archipiélago de San Lorenzo; 16 = Zona Marina Bahía de los Ángeles, Canales de Ballenas y Salsipuedes; 17 = Complejo Lagunar Ojo de Liebre; 18 = El Vizcaíno; 19 = Servidumbre Ecológica Rancho San Cristóbal-Majiben; 20 = Bahía de Loreto; 21 = Reserva Ecológica Llanos de Magdalena; 22 = Reserva Natural El Portezuelo; 23 = Santa Martha; 24 = Zona marina del Archipiélago de Espíritu Santo; 25 = Balandra; 26 = Non-Such; 27 = Sierra La Laguna; 28 = Cabo Pulmo; 29 = Estero de San José del Cabo; and 30 = Cabo San Lucas.

Taxon	Natural Protected Areas																													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
<i>Hemidactylus frenatus</i> ***												+						+									+	+	+	+
<i>Hemidactylus turcicus</i> ***		+																												
Iguanidae (9 species)																														
<i>Ctenosaura hemilopha</i> **												+													+	+	+		+	+
<i>Dipsosaurus catalinensis</i> **												+																		
<i>Dipsosaurus dorsalis</i>		+								+	+	+		+				+	+		+	+	+		+	+	+		+	+
<i>Iguana rhinolopha</i> ***																													+	
<i>Sauromalus ater</i>										+		+						+				+	+		+					
<i>Sauromalus hispidus</i> **												+																		
<i>Sauromalus klauberi</i> **												+																		
<i>Sauromalus slevini</i> **												+																		
<i>Sauromalus varius</i> ***												+																		
Phrynosomatidae (29 species)																														
<i>Callisaurus draconoides</i>		+								+	+	+						+	+	+	+	+	+		+	+	+		+	+
<i>Petrosaurus mearnsi</i>										+		+																		
<i>Petrosaurus repens</i> **										+		+						+				+	+							
<i>Petrosaurus slevini</i> **												+																		
<i>Petrosaurus thalassinus</i> **												+															+			+
<i>Phrynosoma blainvillii</i>	+		+																											
<i>Phrynosoma cerroense</i> **						+	+	+	+	+	+			+				+	+											
<i>Phrynosoma coronatum</i> **																					+	+	+		+	+	+		+	+
<i>Phrynosoma mcallii</i>		+																												
<i>Phrynosoma platyrhinos</i>		+																												
<i>Sceloporus angustus</i> **												+																		
<i>Sceloporus grandaevus</i> **												+																		
<i>Sceloporus hunsakeri</i> **												+													+		+		+	+
<i>Sceloporus licki</i> **																											+			
<i>Sceloporus lineatulus</i> **												+																		
<i>Sceloporus magister</i>		+																												
<i>Sceloporus occidentalis</i>	+		+	+	+				+					+																
<i>Sceloporus orcutti</i>	+			+	+					+	+	+						+				+	+							
<i>Sceloporus vandenburgianus</i>	+			+																										
<i>Sceloporus zosteromus</i> **						+	+	+	+	+	+	+		+				+	+		+	+	+		+	+	+		+	+
<i>Urosaurus graciosus</i>		+								+																				
<i>Urosaurus lahtelai</i> **										+																				
<i>Urosaurus nigricaudus</i>										+	+	+		+				+	+		+	+	+		+	+	+		+	+
<i>Urosaurus ornatus</i>		+																												
<i>Uta encantadae</i> **												+																		
<i>Uta lowei</i> **												+																		
<i>Uta squamata</i> **												+																		
<i>Uta stansburiana</i>	+	+	+	+	+	+	+	+	+	+	+	+		+				+	+	+	+	+	+		+	+	+	+	+	+
<i>Uta tumidarostra</i> **												+																		
Phyllodactylidae (5 species)																														
<i>Phyllodactylus bugastrolepis</i> **												+																		
<i>Phyllodactylus nocticolus</i>										+	+	+		+				+			+	+	+							



**No. 45.** *Rena boettgeri* (Werner, 1899). The Cape Threadsnake is distributed at “low elevations (up to 300 m) in the Cape region of the Baja California Peninsula (Isthmus of La Paz to Cabo San Lucas) and on Isla Cerralvo” (Heimes 2016: 27). This individual came from La Paz, Baja California Sur, in the municipality of La Paz. In this study its EVS was estimated as 14, placing it at the lower limit of the high vulnerability category. This species is not listed by either the IUCN or SEMARNAT. *Photo by Jorge H. Valdez-Villavicencio.*



**No. 46.** *Rena humilis* (Baird and Girard, 1853). The Western Threadsnake “ranges throughout the southwestern United States and western Mexico” (Heimes 2016: 30). This individual was found in Ensenada, Baja California, in the municipality of Ensenada. In this study its EVS was determined as 8, placing it in the upper portion of the low vulnerability category. The IUCN judged its conservation status as Least Concern (LC), but this threadsnake is not listed by SEMARNAT. *Photo by Jorge H. Valdez-Villavicencio.*



**No. 47.** *Thamnophis elegans* (Baird and Girard, 1853). The Western Terrestrial Garter Snake “ranges continuously from southwestern Canada, south through the western United States to central Nevada, Arizona, and New Mexico, nearly to the edges of the Mojave and Sonoran deserts. It is known from isolated populations in the Sierra Nevada and the San Bernardino Mountains of California as well as central New Mexico...In Baja California, *T. elegans* occurs in another isolated population from the Sierra San Pedro Mártir” (Grismer 2002: 308). This individual came from La Grulla, Sierra San Pedro Mártir, in the municipality of Ensenada. In this study its EVS was calculated as 14, placing it at the lower limit of the high vulnerability category. The IUCN judged its conservation status as Least Concern (LC), but SEMARNAT assessed it as Threatened (A). *Photo by Jorge H. Valdez-Villavicencio.*



**No. 48.** *Thamnophis validus* (Kennicott, 1860). The West Coast Garter Snake “has a fragmented distribution along the west coast of southwestern Mexico from southern Sonora south to Guerrero...In Baja California, it also has a fragmented distribution and is known from water systems near La Burrera along the western face of the Sierra La Laguna and the watercourses and systems associated with Santiago, Agua Caliente, and Miraflores along the eastern face of the Sierra La Laguna” (Grismer 2002: 312). This individual is from Miraflores, Baja California Sur, in the municipality of Los Cabos. In this study its EVS was determined as 11, placing it in the lower portion of the medium vulnerability category. The IUCN assessed its conservation status as Least Concern (LC), but this species is not listed by SEMARNAT. *Photo by Tim Warfel.*



The herpetofauna of the Baja California Peninsula

**Table 21 (continued).** Distribution of herpetofaunal species in the Natural Protected Areas of the Baja California Peninsula, Mexico. Abbreviations are as follows: \* = species endemic to Mexico; \*\* = species endemic to Baja California; and \*\*\* = non-native species. The numbers of the Natural Protected Areas signify the following: 1 = Constitución de 1857; 2 = Alto Golfo y Delta del Río Colorado; 3 = Arroyo San Miguel; 4 = Sierra San Pedro Mártir; 5 = Los Montes de San Pedro; 6 = Reserva Natural San Quintín; 7 = Reserva Natural Punta Mazo; 8 = Reserva Natural Monte Ceniza; 9 = Reserva Natural Valle Tranquilo; 10 = Valle de los Cirios; 11 = Costa Salvaje Wildlands; 12 = Islas del Golfo de California; 13 = Isla Guadalupe; 14 = Islas del Pacífico de la Península de Baja California; 15 = Zona Marina del Archipiélago de San Lorenzo; 16 = Zona Marina Bahía de los Ángeles, Canales de Ballenas y Salsipuedes; 17 = Complejo Lagunar Ojo de Liebre; 18 = El Vizcaíno; 19 = Servidumbre Ecológica Rancho San Cristóbal-Majiben; 20 = Bahía de Loreto; 21 = Reserva Ecológica Llanos de Magdalena; 22 = Reserva Natural El Portezuelo; 23 = Santa Martha; 24 = Zona marina del Archipiélago de Espíritu Santo; 25 = Balandra; 26 = Non-Such; 27 = Sierra La Laguna; 28 = Cabo Pulmo; 29 = Estero de San José del Cabo; and 30 = Cabo San Lucas.

Taxon	Natural Protected Areas																													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
<i>Phyllodactylus partidus</i> **												+																		
<i>Phyllodactylus unctus</i> **												+															+		+	+
<i>Phyllodactylus xanti</i> **																									+	+	+		+	+
Scincidae (3 species)																														
<i>Plestiodon gilberti</i>	+			+	+																									
<i>Plestiodon lagunensis</i> **																			+								+			
<i>Plestiodon skiltonianus</i>	+			+	+	+	+	+	+					+																
Teiidae (13 species)																														
<i>Aspidoscelis canus</i> **												+																		
<i>Aspidoscelis carmenensis</i> **												+																		
<i>Aspidoscelis catalinensis</i> **												+																		
<i>Aspidoscelis celeripes</i> **												+																		
<i>Aspidoscelis ceralbensis</i> **												+																		
<i>Aspidoscelis danheimae</i> **												+																		
<i>Aspidoscelis espiritensis</i> **												+																		
<i>Aspidoscelis franciscensis</i> **												+																		
<i>Aspidoscelis hyperythrus</i>			+			+	+	+	+	+	+	+		+				+	+		+	+	+		+	+	+		+	+
<i>Aspidoscelis labialis</i> **						+	+	+	+	+	+							+												
<i>Aspidoscelis maximus</i> **												+													+		+		+	+
<i>Aspidoscelis pictus</i> **												+																		
<i>Aspidoscelis tigris</i>	+		+			+	+	+	+	+	+	+		+				+	+		+	+	+							
Xantusiidae (3 species)																														
<i>Xantusia gilberti</i> **																											+			
<i>Xantusia henshawi</i>	+																													
<i>Xantusia wigginsi</i>									+	+	+							+												
Charinidae (1 species)																														
<i>Lichamura trivirgata</i>	+		+		+				+	+	+	+		+				+			+	+	+		+	+	+		+	+
Colubridae (29 species)																														
<i>Arizona elegans</i>		+	+			+	+	+	+	+	+																			
<i>Arizona pacata</i> **										+								+	+		+									
<i>Bogertophis rosaliae</i>										+		+						+							+		+			
<i>Lampropeltis californiae</i>	+	+	+		+	+	+	+	+	+	+	+						+	+		+	+	+		+	+	+		+	+
<i>Lampropeltis catalinensis</i> **												+																		
<i>Lampropeltis herrerae</i> **														+																
<i>Lampropeltis multifasciata</i>	+			+	+																									
<i>Masticophis aurigulus</i> **																											+			
<i>Masticophis barbouri</i> **												+																		
<i>Masticophis flagellum</i>		+																												
<i>Masticophis fuliginosus</i>			+		+	+	+	+	+	+	+	+		+				+	+		+	+	+		+	+	+		+	+
<i>Masticophis lateralis</i>			+		+	+	+	+	+	+								+												
<i>Phyllorhynchus decurtatus</i>		+								+		+						+				+	+		+	+				
<i>Pituophis catenifer</i>	+	+	+		+	+	+	+	+	+	+			+																
<i>Pituophis insulanus</i> **														+																
<i>Pituophis vertebralis</i> **										+	+	+		+				+	+		+	+	+		+	+	+		+	+
<i>Rhinocheilus etheridgei</i> **												+																		



**No. 49.** *Crotalus angelensis* Klauber, 1963. The Isla Ángel de la Guarda Rattlesnake “is endemic to Isla Ángel de la Guarda in the Gulf of California” (Grismer 2002: 333), from where this individual originated. In this study its EVS was assessed as 18, placing in the upper portion of the high vulnerability category. The IUCN judged its conservation status as Least Concern (LC), but this rattlesnake is not listed by SEMARNAT. *Photo by Tim Warfel.*



**No. 51.** *Crotalus polisi* Meik, Schaack, Flores-Villelam and Streicher, 2018. The Isla Cabeza de Caballo Speckled Rattlesnake or Horsehead Island Speckled Rattlesnake is endemic to Isla Cabeza de Caballo Island in the Gulf of California, municipality of San Quintín. The species EVS was calculated as 19. The species is not listed by the IUCN, but SEMARNAT assessed its conservation status as Special Protection (Pr). *Photo by Tim Warfel.*



**No. 50.** *Crotalus enyo* (Cope, 1861). The Baja California Rattlesnake “ranges throughout most of Baja California. In the north, its contact with the Pacific coast occurs in the vicinity of Cabo Colonet and with the Gulf coast near Bahía de los Angeles. From here, *C. enyo* continues south throughout all of Baja California...It is also known from the Pacific islands of Magdalena and Santa Margarita and the Gulf islands of Carmen, Cerralvo, Coronados, Espíritu Santo, Pardo, Partida Sur, San Francisco, San José, and San Marcos...” (Grismer 2002: 328–329). This individual was found at Guerrero Negro, Baja California Sur, in the municipality of Mulegé. In this study its EVS was estimated as 13, placing it at the upper limit of the medium vulnerability category. The IUCN assessed its conservation status as Least Concern (LC), but SEMARNAT judged its status as Threatened (A). *Photo by Jorge H. Valdez-Villavicencio.*



**No. 52.** *Crotalus pyrrhus* (Cope, 1866). The Southwestern Speckled Rattlesnake is distributed from southeastern Nevada, western Arizona, and southern California southward into the northern half of the Baja California Peninsula (Meik et al. 2015). This individual is from Rancho La Costilla, Sierra San Pedro Mártir, in the municipality of San Quintín. Its EVS was assessed as 13, placing it at the upper limit of the medium vulnerability category. This species is not listed by the IUCN, but it is listed by SEMARNAT as a species of Special Protection (Pr). *Photo by Ivan Parr.*

# The herpetofauna of the Baja California Peninsula

**Table 21 (continued).** Distribution of herpetofaunal species in the Natural Protected Areas of the Baja California Peninsula, Mexico. Abbreviations are as follows: \* = species endemic to Mexico; \*\* = species endemic to Baja California; and \*\*\* = non-native species. The numbers of the Natural Protected Areas signify the following: 1 = Constitución de 1857; 2 = Alto Golfo y Delta del Río Colorado; 3 = Arroyo San Miguel; 4 = Sierra San Pedro Mártir; 5 = Los Montes de San Pedro; 6 = Reserva Natural San Quintín; 7 = Reserva Natural Punta Mazo; 8 = Reserva Natural Monte Ceniza; 9 = Reserva Natural Valle Tranquilo; 10 = Valle de los Cirios; 11 = Costa Salvaje Wildlands; 12 = Islas del Golfo de California; 13 = Isla Guadalupe; 14 = Islas del Pacífico de la Península de Baja California; 15 = Zona Marina del Archipiélago de San Lorenzo; 16 = Zona Marina Bahía de los Ángeles, Canales de Ballenas y Salsipuedes; 17 = Complejo Lagunar Ojo de Liebre; 18 = El Vizcaíno; 19 = Servidumbre Ecológica Rancho San Cristóbal-Majiben; 20 = Bahía de Loreto; 21 = Reserva Ecológica Llanos de Magdalena; 22 = Reserva Natural El Portezuelo; 23 = Santa Martha; 24 = Zona marina del Archipiélago de Espíritu Santo; 25 = Balandra; 26 = Non-Such; 27 = Sierra La Laguna; 28 = Cabo Pulmo; 29 = Estero de San José del Cabo; and 30 = Cabo San Lucas.

Taxon	Natural Protected Areas																														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
<i>Rhinocheilus lecontei</i>	+	+	+			+	+	+	+	+	+																				
<i>Salvadora hexalepis</i>		+	+		+	+	+	+	+	+	+			+					+	+		+	+	+		+	+	+		+	+
<i>Sonora annulata</i>		+																													
<i>Sonora cincta</i> **						+	+	+	+	+	+			+					+	+											
<i>Sonora fasciata</i> **												+		+					+			+	+	+							
<i>Sonora mosaueri</i> **			+							+									+				+	+							
<i>Sonora punctatissima</i> **												+																			
<i>Sonora savagei</i> **												+																			
<i>Sonora straminea</i> **																											+				
<i>Sonora semiannulata</i>		+																													
<i>Tantilla planiceps</i>			+							+		+							+									+			
<i>Trimorphodon lyrophanes</i>			+		+				+	+	+	+							+			+	+		+		+		+		
Dipsadidae (7 species)																															
<i>Diadophis punctatus</i>			+											+																	
<i>Hypsiglena catalinae</i> **												+																			
<i>Hypsiglena chlorophaea</i>		+																													
<i>Hypsiglena gularis</i> **												+																			
<i>Hypsiglena marcosensis</i> **												+																			
<i>Hypsiglena ochrorhynchus</i>			+		+	+	+	+	+	+	+	+		+					+	+		+	+	+		+	+	+		+	+
<i>Hypsiglena slevini</i> **										+		+		+					+			+	+	+		+	+	+		+	+
Elapidae (1 species)																															
<i>Hydrophis platurus</i>												+		+	+	+	+			+				+				+		+	+
Leptotyphlopidae (2 species)																															
<i>Rena boettgeri</i> **																									+		+		+	+	+
<i>Rena humilis</i>		+	+			+	+	+	+	+	+	+		+					+	+		+	+	+		+	+				
Natricidae (3 species)																															
<i>Thamnophis elegans</i>				+																											
<i>Thamnophis hammondi</i>	+		+	+	+					+									+												
<i>Thamnophis validus</i> **																											+		+		
Typhlopidae (1 species)																															
<i>Indotyphlops braminus</i> ***																													+		
Viperidae (12 species)																															
<i>Crotalus angelensis</i> **												+																			
<i>Crotalus atrox</i>		+										+																			
<i>Crotalus catalinensis</i> **												+																			
<i>Crotalus cerastes</i>		+																													
<i>Crotalus enyo</i> **									+	+	+	+		+					+	+		+	+	+		+	+	+		+	+
<i>Crotalus helleri</i>			+	+	+	+	+	+	+	+	+			+					+												
<i>Crotalus lorenzoensis</i> **												+																			
<i>Crotalus mitchellii</i> **												+		+					+	+		+	+	+	+	+	+	+	+	+	+
<i>Crotalus polisi</i> **												+																			
<i>Crotalus pyrrhus</i>	+		+		+	+	+	+	+	+	+	+																			
<i>Crotalus ruber</i>	+	+	+	+	+	+	+	+	+	+	+	+		+					+	+		+	+	+	+	+	+	+	+	+	+
<i>Crotalus thalassoporus</i> **												+																			
Testudines (8 species)																															





**No. 53.** *Crotalus ruber* Cope, 1892. The Red Diamond Rattlesnake is distributed from “Los Angeles County, California, south throughout Baja California to Cabo San Lucas...*Crotalus ruber* is known to occur on the Pacific islands of Cedros and Santa Margarita...and the Gulf islands of Angel de la Guarda, Danzante, Monserrat, Pond, San José, and San Marcos...” (Grismer 2002: 322). This individual was found at Rancho El Coyote, Sierra San Pedro Mártir. The species EVS was determined as 9, placing it at the upper limit of the low vulnerability category. The IUCN assessed its conservation status as Least Concern (LC), and SEMARNAT judged it as a species of Special Protection (Pr). *Photo by Ivan Parr.*



**No. 54.** *Crotalus thalassoporus* Meik, Schaack, Flores-Villela, and Streicher, 2018. The Piojo Island Speckled Rattlesnake or Louse Island Speckled Rattlesnake is endemic to Isla Piojo in the Gulf of California, in the municipality of San Quintín. Its EVS was assessed as 19, placing it in the upper portion of the high vulnerability category. This species is not listed by the IUCN, but SEMARNAT lists it as a species of Special Protection (Pr). *Photo by Tim Warfel.*



**No. 55.** *Actinemys pallida* (Seeliger, 1945). The Southwestern Pond Turtle ranges from the central coast range south of the San Francisco Bay area to northwestern Baja California (<http://www.reptile-database.org/>, accessed 7 December 2022; Grismer 2002: 88), with a disjunct population in the central desert of Baja California (Valdez-Villavicencio et al. 2016). This individual came from Arroyo Valladares, Baja California, in the municipality of San Quintín. In this study its EVS was assessed as 13, placing it at the higher limit of the medium vulnerability category. This species is not listed by either the IUCN or SEMARNAT. *Photo by Jorge H. Valdez-Villavicencio.*

## The herpetofauna of the Baja California Peninsula

**Table 21 (continued).** Distribution of herpetofaunal species in the Natural Protected Areas of the Baja California Peninsula, Mexico. Abbreviations are as follows: \* = species endemic to Mexico; \*\* = species endemic to Baja California; and \*\*\* = non-native species. The numbers of the Natural Protected Areas signify the following: 1 = Constitución de 1857; 2 = Alto Golfo y Delta del Río Colorado; 3 = Arroyo San Miguel; 4 = Sierra San Pedro Mártir; 5 = Los Montes de San Pedro; 6 = Reserva Natural San Quintín; 7 = Reserva Natural Punta Mazo; 8 = Reserva Natural Monte Ceniza; 9 = Reserva Natural Valle Tranquilo; 10 = Valle de los Cirios; 11 = Costa Salvaje Wildlands; 12 = Islas del Golfo de California; 13 = Isla Guadalupe; 14 = Islas del Pacífico de la Península de Baja California; 15 = Zona Marina del Archipiélago de San Lorenzo; 16 = Zona Marina Bahía de los Ángeles, Canales de Ballenas y Salsipuedes; 17 = Complejo Lagunar Ojo de Liebre; 18 = El Vizcaíno; 19 = Servidumbre Ecológica Rancho San Cristóbal-Majibén; 20 = Bahía de Loreto; 21 = Reserva Ecológica Llanos de Magdalena; 22 = Reserva Natural El Portezuelo; 23 = Santa Martha; 24 = Zona marina del Archipiélago de Espíritu Santo; 25 = Balandra; 26 = Non-Such; 27 = Sierra La Laguna; 28 = Cabo Pulmo; 29 = Estero de San José del Cabo; and 30 = Cabo San Lucas.

Taxon	Natural Protected Areas																													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
<b>Cheloniidae (4 species)</b>																														
<i>Caretta caretta</i>												+		+	+	+	+			+				+				+		+
<i>Chelonia mydas</i>												+		+	+	+	+			+				+				+		+
<i>Eretmochelys imbricata</i>												+		+	+	+	+			+				+				+		+
<i>Lepidochelys olivacea</i>												+		+	+	+	+			+				+				+		+
<b>Dermochelyidae (1 species)</b>																														
<i>Dermochelys coriacea</i>												+		+	+	+	+			+				+				+		+
<b>Emydidae (3 species)</b>																														
<i>Actinemys marmorata</i>				+	+					+																				
<i>Trachemys nebulosa</i> **																		+										+		
<i>Trachemys scripta</i> ***																												+		
<b>Total (157 species)</b>																														

eventually be located within one or more of the NPAs.

The most widely distributed species among the NPAs is the phrynosomatid lizard *Uta stansburiana*, which has been recorded from 25 of these areas. A sizeable number of species (69 or 43.9%) have been recorded from only one of the 30 NPAs (Table 21). The remaining 90 species (57.3%) have been recorded in two to 24 NPAs.

In 29 of the 30 NPAs from which herpetofaunal species have been recorded, the total numbers of species range from six to 84 (Table 22). The allocations of these species according to their distributional status are shown in Table 22. Most of the 29 NPAs (22 or 75.9%) lack non-native species, which is a desirable feature. The other seven NPAs support from one to four non-native species ( $\bar{x}$  = 1.7 species). Each of the 29 NPAs have a herpetofauna that contains some number of non-endemic species, which ranges from six to 40. Most of these NPAs also have some country endemic species, ranging from one to 50; however, no country endemic species have been recorded in eight of these areas. Usually the number of non-endemic species exceeds that of the country endemics, except for the Gulf of California Islands (with 32 of the former and 50 of the latter), the Sierra La Laguna (with 18 of the former and 20 of the latter), and the Estero de San José del Cabo (with 15 of each of non-endemic and country endemic species).

Only one of the 30 NPAs in the Baja California Peninsula and its adjacent islands (Isla Guadalupe) lacks a herpetofaunal survey of any magnitude. This island is located 241 km off the western coast of the peninsula and about 400 km southwest of Ensenada in the state of

Baja California. This island and its surrounding islets and waters are part of a biosphere reserve established in 2005 (Table 20). The absence of herpetofaunal documentation on Isla Guadalupe is not due to a lack of effort on the part of herpetologists, as several collecting efforts have been made. For example, the San Diego Natural History Museum sponsored an expedition there years ago, and two authors of this paper (APG and JHVV) also have been on this island and contacted people who are part of an NGO at a base camp. However, none of these efforts resulted in the finding of any amphibians or reptiles on Isla Guadalupe; therefore, it is interesting that apparently no amphibians, and especially no reptiles, have made it to this island.

Of the 81 non-endemic species found in the herpetofauna of the peninsula and its associated islands, 75 (92.6%) have been recorded among the region's NPAs. Of the 77 country endemic species known, 76 (98.7%) are established in protected areas. Fortunately, only seven of the 14 non-native species (50%) have populations established in any of the NPAs, and usually they occur individually in any given area. Only one of these seven non-native species (*Hemidactylus frenatus*) occurs in more than a single NPA, and the number of areas it occurs in is six (Table 21).

The Baja California Peninsula is a unique area of Mexico, as nearly 30% of its land is protected. However, comprehensive herpetological studies are still lacking for most reserves, and the available surveys largely focus on target species (endemics and NOM-59 species). Since several conservation threats affect the natural protected

**Table 22.** Summary of the distributional status of the herpetofaunal species in protected areas in the Baja California Peninsula, Mexico, and adjacent islands. Total = total number of species recorded in a compendium of the listed protected areas.

Protected area	Number of species	Distributional status		
		Non-endemic (NE)	Country Endemic (CE)	Non-native (NN)
Constitución de 1857	26	26	—	—
Alto Golfo y Delta del Río Colorado	28	27	—	1
Arroyo San Miguel	31	30	1	—
Sierra San Pedro Mártir	21	21	—	—
Los Montes de San Pedro	26	26	—	—
Reserva Natural San Quintín	21	17	4	—
Reserva Natural Punta Mazo	22	17	5	—
Reserva Natural Monte Ceniza	21	17	4	—
Reserva Natural Valle Tranquilo	31	25	6	—
Valle de los Cirios	54	40	14	—
Costa Salvaje Wildlands	32	24	8	—
Islas del Golfo de California	84	32	50	2
Islas del Pacífico de la Península de Baja California	43	29	14	—
Zona Marina del Archipiélago de San Lorenzo	6	6	—	—
Zona Marina Bahía de los Ángeles, Canales de Ballenas y Salsipuedes	6	6	—	—
Complejo Lagunar Ojo de Liebre	6	6	—	—
El Vizcaíno	48	30	16	2
Servidumbre Ecológica Rancho San Cristóbal-Majiben	24	14	10	—
Bahía de Loreto	9	9	—	—
Reserva Ecológica Llanos de Magdalena	26	16	10	—
Reserva Natural El Portezuelo	31	21	10	—
Santa Martha	30	21	9	—
Zona marina del Archipiélago de Espíritu Santo	8	7	1	—
Balandra	31	20	11	—
Non-Such	26	16	10	—
Sierra La Laguna	39	18	20	1
Cabo Pulmo	10	8	1	1
Estero de San José del Cabo	34	15	15	4
Cabo San Lucas	30	17	12	1
<b>Total</b>	<b>157</b>	<b>75</b>	<b>76</b>	<b>7</b>

areas, a substantial amount of work is necessary to achieve effective resource management and ensure the conservation of the amphibian and reptile species in the Baja California Peninsula, both inside and outside of the NPAs.

## Conclusions and Recommendations

### Conclusions

- The herpetofauna of the Baja California Peninsula is comprised of 172 species, including 18 anurans, three salamanders, 140 squamates (83 lizards and 57 snakes), and 11 turtles.
- The numbers of species known from the 10 geographic regions we recognize in the Baja California Peninsula range from 27 in the Baja California Coniferous Forest Region to 84 in the Gulf Islands Region. The species occupy from one to 10 geographic regions, with a mean number of 3.3.

- The number of species shared among the 10 geographic regions ranges from eight between the BCCFR and SLLR regions to 54 between the CGCR and ATR regions. The Coefficient of Biogeographic Resemblance values range from 0.16 between BCCFR and GIR to 0.86 between CGCR and ATR. The UPGMA dendrogram (Fig. 24) demonstrates that the two most closely related regions are the Central Gulf Coast Region and the Arid Tropical Region, which are joined at the 0.86 level. These two regions are joined at the 0.82 level with the Magdalena Region. These three regions are joined at the 0.74 level with the Vizcaíno Region. These four regions are joined at the 0.64 level with the Sierra La Laguna Region. This group of five regions in the southern portion of the Peninsula is joined to the remaining regions in the northern portion of the Peninsula and those in the Pacific Ocean and the Gulf of California at the 0.52 level. Of the remaining five regions, the ones most closely allied are the Pacific



Islands Region and the California Region, joined at the 0.62 level. These two regions are united to the other three regions at the 0.51 level with the Lower Colorado Valley Region. The eight previously mentioned peninsular regions are joined to the Gulf Islands Region at the 0.44 level. Finally, the most distantly related region is the Baja California Coniferous Forest Region, which is joined to all the other regions at the 0.33 level.

- D. The level of herpetofaunal endemism in the Baja California Peninsula is relatively high. Of the 158 species that make up the native herpetofauna, 77 are peninsular endemics (48.7%).
- E. The distributional status of the species that comprise the herpetofauna of the Baja California Peninsula is as follows (in order of category size): non-endemics (81, 47.1%); peninsular endemics (77, 43.6%); and non-natives (14, 8.1%).
- F. With respect to the distributional categories instituted by Wilson et al. (2017), of the 81 non-endemic species, 74 (91.4%) are in the MXUS category, with one (1.2%) in the USCA category and six (7.4%) in the OCEA category.
- G. The principal environmental threats are land conversion and habitat loss, water diversion and overuse, invasive species, livestock grazing, illegal trade, off-road activities, infectious diseases, and climate change.
- H. To evaluate the conservation status of the herpetofauna of the Baja California Peninsula, we used the SEMARNAT, IUCN, and EVS systems. SEMARNAT lists 85 (53.8%) of the 158 native species, including seven categorized as endangered (P), 33 as threatened (A), and 45 as special protection (Pr). A comparison of the SEMARNAT and distributional categorizations demonstrates that of the seven endangered species, all are non-endemics; of the 33 threatened species, 13 are non-endemics and 20 are peninsular endemics; and of the 45 special protection species, 19 are non-endemics and 26 are peninsular endemics.
- I. Application of the IUCN conservation status evaluation categories to the herpetofauna of the Baja California Peninsula indicates the following distribution (by category and proportion): CR (three, 1.9%); EN (four, 2.5%); VU (eight, 5.1%); NT (seven, 4.4%); LC (108, 68.4%); DD (three, 1.9%); and NE (25, 15.8%).
- J. Application of the EVS system of conservation assessment to the 152 non-marine native species of the Baja California Peninsula indicates that the categorical values increase from low scores (28 species, 18.4%) to medium scores (48 species, 31.6%), and then to high scores (76 species, 50.0%).
- K. A comparison of the IUCN and EVS conservation status categorizations indicates that nine (11.8%)

of the 76 high vulnerability species (by EVS) are allocated to one of the three IUCN “threat categories” (CR, EN, or VU), and that 26 (92.9%) of the 28 low vulnerability species are placed in the LC category.

- L. Application of the Relative Herpetofauna Priority (RHP) measure demonstrates that the most significant herpetofauna in the Baja California Peninsula is that of the Gulf Islands Region, inasmuch as it contains the highest numbers of peninsular endemic species and high vulnerability species. The ratings of seven of the 10 geographic regions are the same whether based on peninsular endemic species or high vulnerability species.
- M. Thirty protected areas are established in the Baja California Peninsula, with 17 administered at the federal level, two at the state level, and 11 at the private level. The 30 protected areas comprise almost one-half of the total area of the Baja California Peninsula.
- N. Of the 158 species that comprise the native herpetofauna of the Baja California Peninsula, only eight (two country endemics and six non-endemics) are not represented in the system of protected areas in the region. Of the 30 established NPAs, only one (Isla Guadalupe) is not known to contain any herpetofaunal species.
- O. The most widely distributed species represented with the system of NPAs is the lizard *Uta stansburiana*, which occupies 25 of the 29 supporting herpetofaunal populations. Sixty-nine species are known from only a single NPA, while 90 species occupy from two to 24 NPAs.
- P. The total numbers of species occupying the 29 NPAs range from six to 84. Twenty-two of the 29 NPAs support no non-native species, which is a desirable feature. A typical NPA supports more non-native than country endemic species.
- Q. Of the 83 non-endemic species recorded on the peninsula and its associated islands, 75 (90.4%) are known from among the region’s NPAs; of the 77 country endemics, 76 (98.7%) are represented. The total representation is 151 of 158 species, or 95.6%, which is outstanding from a conservation perspective. Also, of major interest from this perspective, nearly 30% of the area in the Baja California Peninsula is protected, even though herpetofaunal surveys are unavailable for most of the NPAs.

### Recommendations

- A. Prioritize the evaluation of species to be included in NOM-059-SEMARNAT, based on those that have high vulnerability EVS values, especially peninsular endemics.

- B. Promote eradication programs for non-native species, as both states in the peninsula have the highest numbers of non-native amphibian and reptile species in Mexico. These control and eradication efforts are important to avoid future detrimental effects on native species of amphibians and reptiles.
- C. Evaluate changes to the EVS criteria in order to consider regional threats that affect species of amphibians in desert areas.
- D. Because herpetofaunal surveys have not been conducted in many of the protected areas, this remains a major goal for these areas in the future. Achieving this goal will require a determination of the presence or absence of the eight native species that are not represented within the system of protected areas.
- E. Once the entire native herpetofauna is demonstrated to occur within the confines of the system of protected areas, monitoring programs can be established to continually assess the health of the populations of all species.

“In a country with phenomenal natural riches, Baja California and its offshore islands stand out as a priceless setting for studying the factors that shape ecological communities, and they are replete with stunningly beautiful locales for recreation and education.”

Harry W. Greene (Foreword in Grismer, 2002)

**Acknowledgments.**—We thank Alan Harper, Felipe León, Gerardo Marrón, Ivan Parr, José Antonio Soriano, Andrea Navarro Tiznado, and Tim Warfel for providing some of the images utilized in this paper. We also are grateful to Vitza Cabrera, Noé López, Héctor M. Sánchez, and Flor Torres for providing information on the natural protected areas, and Rafael Lara Reséndiz for his help in searching for climate and precipitation data. Finally, we are thankful to Clark Mahrtdt and an anonymous reviewer for their helpful reviews of our manuscript.

## Literature Cited

- Adams A, Peralta-García A, Flores-López CA, Valdez-Villavicencio JH, Briggs CJ. 2022. High fungal pathogen loads and prevalence in Baja California amphibian communities: the importance of species, elevation, and historical context. *Global Ecology and Conservation* 33: e01968.
- Adams AJ, Pessier AP, Briggs CJ. 2017. Rapid extirpation of a North American frog coincides with an increase in fungal pathogen prevalence: historical analysis and implications for reintroduction. *Ecology and Evolution* 7: 10,216–10,232.
- Aguirre-Muñoz A, Samaniego-Herrera A, Luna-Mendoza L, Ortiz-Alcaraz A, Méndez-Sánchez F, Hernández-Montoya J. 2016. La restauración ambiental exitosa de las islas de México: una reflexión sobre los avances a la fecha y los retos por venir. Pp. 485–512 In: *Experiencias Mexicanas en la Restauración de los Ecosistemas*. Editors, Ceccon E, Martínez-Garza C. UNAM, CRIM, UAEM and CONABIO, México, DF, Mexico. 577 p.
- Álvarado-Díaz J, Suazo-Ortuño I, Wilson LD, Medina-Aguilar O. 2013. Patterns of physiographic distribution and conservation status of the herpetofauna of Michoacán, Mexico. Contribution to Special Mexico Issue. *Amphibian & Reptile Conservation* 7: 128–170 (e71).
- Álvarez-Borrego S. 2002. Physical oceanography. Pp. 41–59 In: *A New Island Biogeography of the Sea of Cortés*. Editors, Case TJ, Cody ML, Ezcurra E. Oxford University Press, New York, New York, USA. 690 p.
- Alves-Ferreira G, Talora DC, Solé M, Cervantes-López MJ, Heming NM. 2022. Unraveling global impacts of climate change on amphibian distributions: a life-history and biogeographic-based approach. *Frontiers in Ecology and Evolution* 10: 987237.
- Arguelles-Méndez C, Ortega-Rubio A, Romero-Schmidt H, Coria-Benet R, Solis-Marín F. 1996. Pacific Treefrog population changes as a response to the absence of livestock grazing. *Herpetology* 26: 1–4.
- Arnaud G, Martins M, Burguete-Trujillo L, Hernández-Rodríguez I, Avila-Villegas H, Murillo-Quero R, Quijada-Mascareñas A. 2008. Historia natural de las serpientes de cascabel *Crotalus catalinensis*, endémica de la isla Santa Catalina, Golfo de California, México. Pp. 93–100 In: *Estudios de las Islas del Golfo de California*. Editor, Flores-Campaña LM. Universidad Autónoma de Sinaloa-Gobierno del Estado de Sinaloa-Consejo Nacional de Ciencia y Tecnología, México, DF, Mexico. 252 p.
- Arriaga L. 2006. La península de Baja California: biodiversidad, conservación y manejo de sus recursos vegetales. Pp. 64–84 In: *Manejo, Conservación y Restauración de Recursos Naturales en México*. Coordinators, Oyama K, Castillo A. Siglo XXI, México, DF, Mexico. 368 p.
- Auliya M, Altherr S, Ariano-Sánchez D, Baard EH, Brown C, Brown RM, Ziegler T. 2016. Trade in live reptiles, its impact on wild populations, and the role of the European market. *Biological Conservation* 204: 103–119.
- Badan-Dangon A, Robles JM, García J. 1989. Poleward flows off Mexico’s Pacific coast. Pp. 176–202 In: *Poleward Flows Along Eastern Ocean Boundaries. Coastal and Estuarine Studies, 34*. Editors, Neshyba SJ, Mooers CNK, Smith RL, Barber RT. Springer, New York, New York, USA. 374 p.
- Ballesteros-Barrera C, Tapia-Pérez O, Zárate-Hernández R, Leyte-Manrique A, Martínez-Bernal A, Vargas-Miranda B, Martínez-Coronel M, Ortiz-Burgos S. 2022. The potential effect of climate change on the distribution of endemic anurans from Mexico’s

- Tropical Dry Forest. *Diversity* 14: 650.
- Barragan-Vázquez MDR, Ríos Rodas L, Fucsko LA, Porras LW, Mata-Silva V, Rocha A, DeSantis DL, García-Padilla E, Johnson JD, Wilson LD. 2022. The herpetofauna of Tabasco, Mexico: composition, distribution, and conservation status. *Amphibian & Reptile Conservation* 16(2) [General Section]: 1–61 (e315).
- Bellard C, Bertelsmeier C, Leadley P, Thuiller W, Courchamp F. 2012. Impacts of climate change on the future of biodiversity. *Ecology Letters* 15: 365–377.
- Bellard C, Leclerc C, Courchamp F. 2013. Impact of sea level rise on the 10 insular biodiversity hotspots. *Global Ecology and Biogeography* 23: 203–212.
- Bellard C, Marino C, Courchamp F. 2022. Ranking threats to biodiversity and why it doesn't matter. *Nature Communications* 13: 2,616.
- Blackburn TM, Bellard C, Ricciardi A. 2019. Alien versus native species as drivers of recent extinctions. *Frontiers in Ecology and the Environment* 17: 203–207.
- Blaustein AR, Walls SC, Bancroft BA, Lawler JJ, Searle CL, Gervasi SS. 2010. Direct and indirect effects of climate change on amphibian populations. *Diversity* 2: 281–313.
- Böhm M, Collen B, Baillie JEM, Bowles P, Chanson J, Cox N, Hammerson G, Hoffmann M, Livingstone SR, Ram M, et al. 2013. The conservation status of the world's reptiles. *Biological Conservation* 157: 372–385.
- Bolom-Huet R, Pineda E, Díaz-Fleischer F, Muñoz-Alonso AL, Galindo-González J. 2019. Known and estimated distribution in Mexico of *Batrachochytrium dendrobatidis*, a pathogenic fungus of amphibians. *Biotropica* 51: 731–746.
- Bostic DL. 1971. Herpetofauna of the Pacific coast of north central Baja California, Mexico, with a description of a new subspecies of *Phyllodactylus xanti*. *Transactions of the San Diego Society of Natural History* 16: 237–264.
- Bury RB, Luckenbach RA, Busack SD. 1977. *Effects of Off-road Vehicles on Vertebrates in the California Desert. Wildlife Research Report Number 8*. United States Fish and Wildlife Service, Washington, DC, USA. 23 p.
- Bury RB, Welsh HH, Germano DJ, Ashton DT. 2012. *Western Pond Turtle: Biology, Sampling Techniques, Inventory and Monitoring, Conservation, and Management. Northwest Fauna Number 7*. Society for Northwestern Vertebrate Biology, Olympia, Washington, USA. 128 p.
- Busack SD, Bury RB. 1974. Some effects of off-road vehicles and sheep grazing on lizard populations in the Mojave Desert. *Biological Conservation* 6: 179–183.
- Carrillo-Guerrero Y. 2010. *Diagnostico de la Cuenca de La Paz. Reporte Final*. Niparajá-Pronatura Noroeste. La Paz, Baja California Sur, Mexico. 42 p.
- Carter ET, Eads BC, Ravesi MJ, Kingsbury BA. 2015. Exotic invasive plants alter thermal regimes: implications for management using a case study of a native ectotherm. *Functional Ecology* 29: 683–693.
- Cox CL, Davis-Rabosky AR, Holmes IA, Reyes-Velasco J, Roelke CE, Smith EN, Flores-Villela O, McGuire JA, Campbell JA. 2018. Synopsis and taxonomic revision of three genera in the snake tribe Sonorini. *Journal of Natural History* 52: 945–988.
- Cox N, Young BE, Bowles P, Fernandez MF, Marin J, Rapacciuolo G, Böhm M, Brooks TM, Hedges SB, Hilton-Taylor C, et al. 2022. A global reptile assessment highlights shared conservation needs of tetrapods. *Nature* 605: 285–290.
- Cruz-Elizalde R, Ramírez-Bautista A, Pineda-López R, Mata-Silva V, DeSantis DL, García-Padilla E, Johnson JD, Fucsko LA, Wilson LD. 2022. The herpetofauna of Querétaro, Mexico: composition, distribution, and conservation status. *Amphibian & Reptile Conservation* 16(1) [General Section]: 148–192 (e308).
- Cruz-Sáenz D, Muñoz-Nolasco FJ, Mata-Silva V, Johnson JD, García-Padilla E, Wilson LD. 2017. The herpetofauna of Jalisco, Mexico: composition, distribution, and conservation status. *Mesoamerican Herpetology* 4: 22–118.
- Delgadillo J. 2004. *El Bosque de Coníferas de la Sierra San Pedro Mártir, Baja California, México*. Instituto Nacional de Ecología, SEMARNAT, México, DF, Mexico. 159 p.
- DOF (Diario Oficial de la Federación). 2020. Disponibilidad de agua en Baja California Sur. Comisión Estatal del Agua de Baja California Sur. Available: <https://cea.bcs.gob.mx/acuiferos/> [Accessed: 5 December 2022].
- Frost DR. 2022. Amphibian Species of the World: an Online Reference. Version 6.0. American Museum of Natural History, New York, New York, USA. Available: <https://amphibiansoftheworld.amnh.org> [Accessed: 6 December 2022].
- Gaeta-Verdín MC. 2020. Efecto de las actividades de vehículos fuera de camino en el paisaje de Baja California. Master's Thesis. Centro de Investigación Científica y Educación Superior de Ensenada, Ensenada, México. 119 p.
- Galina-Tessaro P, López-Acosta D, Álvarez-Cárdenas S, Valdez-Villavicencio JH, Breceda A, Arnaud GF, Rivera J, Coria BR. 2015. *Contribución a la Distribución, Ecología y Estado de Conservación de dos Especies del Género Sceloporus, Endémicas de la Región del Cabo, Baja California Sur. Informe final SNIB-CONABIO, proyecto No. HK012*. Centro de Investigaciones Biológicas del Noroeste, México, DF, Mexico. 113 p.
- García RA, Clusella-Trullas S. 2019. Thermal landscape change as a driver of ectotherm responses to plant



- invasions. *Proceedings of the Royal Society B* 286: 20191020.
- Garcillán PP, González-Abraham C, Ezcurra E. 2012. Phytogeography, vegetation, and ecological regions. Pp. 23–34 In: *Baja California Plant Field Guide*. 3<sup>rd</sup> Edition. Editors, Rebman JP, Roberts NC. San Diego Natural History Museum, San Diego, California, USA. 480 p.
- Gatica-Colima AB. 1998. Herpetofauna y vegetación de un gradiente de perturbación en las dunas costeras de San Felipe, Baja California, México. Master's Thesis. Facultad de Ciencias, Universidad Autónoma de Baja California, Ensenada, BC, México.
- Gibbons JF, Scott DE, Ryan TJ, Buhlmann KA, Tuberville TD, Metts BS, Greene JL, Mills T, Leiden Y, Poppy S, et al. 2000. The global decline of reptiles, déjà vu amphibians. *Bioscience* 50: 653–666.
- González-Abraham CE, Garcillán PP, Ezcurra E, Grupo de Trabajo Ecorregiones. 2010. Ecorregiones de la península de Baja California: una síntesis. *Boletín de la Sociedad Botánica de México* 87: 69–82.
- González-Sánchez VH, Johnson JD, García-Padilla E, Mata Silva V, DeSantis DL, Wilson LD. 2017. The herpetofauna of the Mexican Yucatan Peninsula: composition, distribution, and conservation. *Mesoamerican Herpetology* 4: 263–380.
- González-Sánchez VH, Johnson JD, González-Solís D, Fucsko LA, Wilson LD. 2021. A review of the introduced herpetofauna of Mexico and Central America, with comments on the effects of invasive species and biosecurity methodology. *ZooKeys* 1022: 79–154.
- González-Zamorano P, Nava-Sánchez EH, León-de la Luz JL, Díaz-Castro SC. 2011. Patrones de distribución y determinantes ambientales de los mangles peninsulares. Pp. 67–102 In: *Los Mangles de la Península de Baja California*. Editors, Félix-Pico EF, Serviere-Zaragoza E, Riosmena-Rodríguez R, León-de la Luz JL. CICIMAR, CIBNOR y UABCS, México, DF, Mexico. 326 p.
- Goode MJ, Swann DE, Schwalbe CR. 2004. Effects of destructive collecting practices on reptiles: a field experiment. *Journal of Wildlife Management* 68: 429–434.
- Goode MJ, Horrace WC, Sredl MJ, Howland JM. 2005. Habitat destruction by collectors associated with decreased abundance of rock-dwelling lizards. *Biological Conservation* 125: 47–54.
- Graciano JC. 2013. Uso del agua y agricultura de exportación en Baja California Sur. Perspectivas desde el agro para el desarrollo regional. Master's Thesis. Universidad Autónoma de Baja California Sur, Ensenada, BC, Mexico. 177 p.
- Grismer LL. 1994. The origin and evolution of the peninsular herpetofauna of Baja California, México. *Herpetological Natural History* 2: 51–106.
- Grismer LL. 2002. *Amphibians and Reptiles of Baja California, including Its Pacific Islands and the Islands in the Sea of Cortés*. University of California Press, Berkeley, California, USA. xii + 399 p.
- Grismer LL, McGuire JA. 1993. The oases of central Baja California, México. Part I. A preliminary account of the relict mesophilic herpetofauna and the status of the oases. *Bulletin of the Southern California Academy of Sciences* 92: 2–24.
- Hastings JR, Turner RM. 1965. Seasonal precipitation regimes in Baja California, México. *Geografiska Annaler* 47A: 204–223.
- Haynes E, Pohly A, Clifford DL, Patterson LC, Manning S, Wack RF, Allender MC. 2021. First report of ophidiomycosis in a free-ranging California Kingsnake (*Lampropeltis californiae*) in California, USA. *Journal of Wildlife Diseases* 57: 246–249.
- Heimes P. 2016. *Snakes of Mexico. Herpetofauna Mexicana. Volume 1*. Edition Chimaira, Frankfurt am Main, Germany, and ECO Publishing, Rodeo, New Mexico, USA. 572 p.
- Hickey B. 1979. The California current system: hypotheses and facts. *Progress in Oceanography* 8: 191–279.
- Holland DC. 1994. *The Western Pond Turtle: Habitat and History. Final Report*. United States Department of Energy, Portland, Oregon, USA. 303 p.
- Hollingsworth BD, Mahrtdt CR, Grismer LL, Banta BD, Sylber CK. 1997. The occurrence of *Sauromalus varius* on a satellite islet of Isla Salsipuedes, Gulf of California, México. *Herpetological Review* 28: 26–28.
- Hollingsworth BD, Mahrtdt CR, Grismer LL, Lovich RE. 2015. Herpetofauna of Baja California. Pp. 15–33 In: *Amphibians and Reptiles of the US-Mexico Border States/Anfibios y reptiles de los estados de la frontera México-Estados Unidos*. Editor, Lemos-Espinal JA. Texas A&M University Press, College Station, Texas, USA. 614 p.
- Humphrey RR. 1974. *The Boojum and its Home*. University of Arizona Press, Tucson, Arizona, USA. 214 p.
- Jaramillo V. 1994. *Revegetación y Reforestación de las Áreas Ganaderas en las Zonas Áridas y Semiáridas de México*. Secretaria de Agricultura y Recursos Hidráulicos, Subsecretaria de Ganadería, Comisión Técnico Consultiva de Coeficientes de Apostadero. México, DF, Mexico. 48 p.
- Jennings MR, Hayes MP. 1994. *Amphibian and Reptile Species of Special Concern in California*. California Department of Fish and Game, Inland Fisheries Division, Rancho Cordova, California, USA. 255 p.
- Jofré GM, Reading CJ. 2012. An assessment of the impact of conservation grazing on reptile populations. *Amphibian and Reptile Conservation Research Report* 12/01: 1–48.
- Johnson, JD, Mata-Silva V, García-Padilla E, Wilson LD. 2015 The herpetofauna of Chiapas, Mexico:

- composition, distribution, and conservation. *Mesoamerican Herpetology* 2: 271–329.
- Kats LB, Ferrer RP. 2003. Alien predators and amphibian declines: review of two decades of science and transition to conservation. *Diversity and Distributions* 9: 99–110.
- Kurczyn JA, Pérez-Brunius P, López M, Candela J, Delgadillo-Hinojosa F, García-Mendoza E. 2019. Water masses and ocean currents over the continental slope off northern Baja California. *Journal of Geophysical Research: Oceans* 124: 2,803–2,823.
- Lambert MR, Hernández-Gómez O, Krohn AR, Mutlow A, Patterson LC, Rosenblum EB, Timmer M, Willis J, Bushell J. 2021. Turtle shell disease fungus (*Emydomyces testavorans*): first documented occurrence in California and prevalence in free-living turtles. *Ichthyology & Herpetology* 109: 958–962.
- Lara-Reséndiz RA, Galina-Tessaro P, Pérez-Delgadillo AG, Valdez Villavicencio JH, Méndez-de la Cruz FR. 2019. Efectos del cambio climático en una especie de lagartija termófila de amplia distribución (*Dipsosaurus dorsalis*): un enfoque ecofisiológico. *Revista Mexicana de Biodiversidad* 90: e902888.
- Lara-Reséndiz RA, Galina-Tessaro P, Sinervo B, Miles DB, Valdez-Villavicencio JH, Valle-Jiménez FI, Méndez-de la Cruz FR. 2020. How will climate change impact fossorial lizard species? Two examples in the Baja California Peninsula. *Journal of Thermal Biology* 95: 102811.
- Lara-Reséndiz RA, Rosen PC, Sinervo B, Miles DB, Mendez-de la Cruz FR. 2022. Habitat thermal quality for *Gopherus evgoodei* in tropical deciduous forest and consequences of habitat modification by buffelgrass. *Journal of Thermal Biology* 104: 103192.
- Lavín MF, Marinone SG. 2003. An overview of the physical oceanography of the Gulf of California. Pp. 173–204 In: *Nonlinear Processes in Geophysical Fluid Dynamics*. Editors, Velasco Fuentes OU, Sheinbaum J, Ochoa J. Springer, Dordrecht, Germany. 376 p.
- Lazcano D, Nevárez-de los Reyes M, García-Padilla E, Johnson JD, Mata-Silva V, DeSantis DL, Wilson LD. 2019. The herpetofauna of Coahuila, Mexico: composition, distribution, and conservation status. *Amphibian & Reptile Conservation* 13(2) [General Section]: 31–94 (e189).
- Leaché AD, Koo MS, Spencer CL, Papenfuss TJ, Fisher RN, McGuire JA. 2009. Quantifying ecological, morphological, and genetic variation to delimit species in the Coast Horned Lizard species complex (*Phrynosoma*). *Proceedings of the National Academy of Sciences of the United States of America* 106: 12,418–12,423.
- Leclère D, Obersteiner M, Barrett M, Butchart SHM, Yung L. 2020. Bending the curve of terrestrial biodiversity needs an integrated strategy. *Nature* 585: 551–556.
- Leyte-Manrique A, Mata-Silva V, Báez-Montes O, Fucsko LA, DeSantis DL, García-Padilla E, Rocha A, Johnson JD, Porras LW, Wilson LD. 2022. The herpetofauna of Guanajuato, Mexico: composition, distribution, and conservation status. *Amphibian & Reptile Conservation* 16(2) [General Section]: 133–180 (e321).
- Lovich LE, Grismer LL, Danemann G. 2009. Conservation status of the herpetofauna of Baja California, México and associated islands in the Sea of Cortez and Pacific Ocean. *Herpetological Conservation and Biology* 4: 358–378.
- Lowe S, Browne M, Boudjelas S, De Poorter M. 2000. *100 of the World's Worst Invasive Alien Species. A Selection from the Global Invasive Species Database of the Species Specialist Group (ISSG) a specialist group of the Species Survival Commission (SSC)*. World Conservation Union (IUCN), Gland, Switzerland. 12 p.
- Luja VH, Rodríguez-Estrella R, Ratzlaff K, Parra-Olea G, Ramírez-Bautista A. 2012. The chytrid fungus *Batrachochytrium dendrobatidis* in isolated populations of the Baja California Treefrog *Pseudacris hypochondriaca curta* in Baja California Sur, Mexico. *Southwestern Naturalist* 57: 323–327.
- Luja VH, Rodríguez-Estrella R, Rojas-González RI. 2016. Reproducción y abundancia de la rana arborícola de Baja California *Pseudacris hypochondriaca curta* (Anura: Hylidae) en oasis de Baja California Sur. Pp. 77–100 In: *Ecología y Conservación de Anfibios y Reptiles de México. Publicación Especial No. 4*. Editors, Gutiérrez-Mayen MG, Ramírez-Bautista A, Pineda E. Sociedad Herpetológica Mexicana, México, DF, Mexico. 396 p.
- Mahrtdt CR, Beaman KR, Valdez-Villavicencio JH, Papenfuss TJ. 2022. *Bipes biporus* (Five-toed Worm Lizard). *Catalogue of American Amphibian and Reptiles* 930: 1–39.
- Manriquez-Gomez FJ, González-Gutiérrez NS, Ortiz-Serrato L, Moreno-Higareda HR, Valdez-Villavicencio JH. 2021. Anfibios y reptiles del Estero de Punta Banda, Ensenada, Baja California, México. *Revista Latinoamericana de Herpetología* 4: 74–84.
- Markham CG. 1972. Baja California's climate. *Weatherwise* 25: 66–101.
- Marshall BM, Strine C, Hughes AC. 2020. Thousands of reptile species threatened by under-regulated global trade. *Nature Communications* 11: 4,738.
- Mata-Silva V, Johnson JD, Wilson LD, García-Padilla E. 2015. The herpetofauna of Oaxaca, Mexico: composition, physiographic distribution, and conservation. *Mesoamerican Herpetology* 2: 5–62.
- Mata-Silva V, Fucsko LA, Gatira Colima AB, Nevárez-de los Reyes M, Lazcano D, Valdez Villavicencio J, Porras LW, DeSantis DL, Rocha A, Johnson JD, et al. [In press]. Biological connections: the uncertain future of the threatened U.S.-Mexico border region herpetofauna. *Zootaxa* [In Press].

- Meigs P. 1966. Geography of coastal deserts. *Arid Zone Research* 28: 1–140.
- Meik JM, Streicher JW, Lawing AM, Flores-Villela O, Fujita MK. 2015. Limitations of climatic data for inferring species boundaries: insights from Speckled Rattlesnakes. *PLoS One* 10: e0131435.
- Meiri S, Bauer AM, Chirio L, Colli GR, Das I, Doan TM, Feldman A, Castro-Herrera F, Novosolov M, Pafilis P, et al. 2013. Are lizards feeling the heat? A tale of ecology and evolution under two temperatures. *Global Ecology and Biogeography* 22: 834–845.
- Mellink E. 1995. The potential effect of commercialization of reptiles from Mexico's Baja California peninsula and its associated islands. *Herpetological Natural History* 3: 95–99.
- Mellink E, Contreras J. 2014. Impacts of ranching on wildlife in Baja California. In: *Conservation Science in Mexico's Northwest: Ecosystem Status and Trends in the Gulf of California*. Editors, Wehncke EV, Lara-Lara JR, Álvarez-Borrego S, Ezcurra E. University of California Institute for Mexico and the United States (UC MEXUS) and Instituto Nacional de Ecología y Cambio Climático (INECC), México, DF, Mexico. 550 p.
- Munguía-Vega A, Rodríguez-Estrella R, Shaw WW, Culver M. 2013. Localized extinction of an arboreal desert lizard caused by habitat fragmentation. *Biological Conservation* 157: 11–20.
- Murray S, Shedd JD, Dugan EA. 2015. *Hypsiglena slevini*. Geographic distribution. *Herpetological Review* 46: 62.
- Nevárez-de los Reyes M, Lazcano D, García-Padilla E, Mata-Silva V, Johnson JD, Wilson LD. 2016. The herpetofauna of Nuevo León, Mexico: composition, distribution, and conservation. *Mesoamerican Herpetology* 3: 557–638.
- Pampa-Ramírez JT. 2021. Propuesta de manejo para la conservación de la culebra real de Todos Santos (*Lampropeltis zonata herrerae*) en Ensenada Baja California, México. Master's Thesis. Facultad de Ciencias, Universidad Autónoma de Baja California, Ensenada, BC, Mexico. 130 p.
- Pase CP. 1982. Sierran montane conifer forest. Pp. 49–51 In: *Biotic Communities of the American Southwest: United States and Mexico*. Editor, Brown DE. University of Arizona for the Boyce Thompson Southwestern Arboretum, Tucson, Arizona, USA. 342 p.
- Peinado M, Alcaraz F, Delgadillo J, Aguado I. 1994. Fitogeografía de la península de Baja California, México. *Anales del Jardín Botánico de Madrid* 51: 255–277.
- Peralta-García A, Adams AJ, Briggs CJ, Galina-Tessaro P, Valdez-Villavicencio JH, Hollingsworth BD, Shaffer HB, Fisher RN. 2018. Occurrence of *Batrachochytrium dendrobatidis* in anurans of the Mediterranean region of Baja California, México. *Diseases of Aquatic Organisms* 127: 193–200.
- Peralta-García A, Hollingsworth BD, Richmond JQ, Valdez-Villavicencio JH, Ruiz-Campos G, Fisher RN, Cruz-Hernández P, Galina-Tessaro P. 2016. Status of the California Red-legged Frog (*Rana draytonii*) in the state of Baja California, México. *Herpetological Conservation and Biology* 11: 168–180.
- Peralta-García A, Samaniego-Herrera A, Valdez-Villavicencio JH. 2007. Registros nuevos de reptiles en islas del Noroeste de México. *Acta Zoológica Mexicana (n.s.)* 23: 179–182.
- Peralta-García A, Valdez-Villavicencio JH. 2004. *Ensatina eschscholtzii eschscholtzii*. Geographic distribution. *Herpetological Review* 35: 279.
- Pereira HM, Leadley PW, Proenca V, Alkemade R, Scharlemann JPW, Fernandez-Manjarres JF, Araujo MB, Balvanera P, Biggs R, Cheung WWL, et al. 2010. Scenarios for global biodiversity in the 21<sup>st</sup> century. *Science* 330: 1,496–1,501.
- Pianka EP. 1966. Convexity, desert lizards, and spatial heterogeneity. *Ecology* 47: 1,055–1,059.
- Pliego-Sánchez JV, Blair C, Díaz de la Vega-Pérez AH, Jiménez-Arcos VH. 2021. The insular herpetofauna of Mexico: composition, conservation, and biogeographic patterns. *Ecology and Evolution* 2021: 1–14.
- Ramírez-Bautista A, Hernández-Salinas U, Cruz-Elizalde R, Berriozabal-Islas C, Moreno-Lara I, DeSantis DL, Johnson JD, García-Padilla E, Mata-Silva V, Wilson LD. 2020. The herpetofauna of Hidalgo, Mexico: composition, distribution, and conservation status. *Amphibian & Reptile Conservation* 14(1) [General Section]: 63–118 (e224).
- Rodríguez-Estrella R, Pérez-Navarro JJ, Granados B, Rivera L. 2010. The distribution of an invasive plant in a fragile ecosystem: the Rubber Vine (*Cryptostegia grandiflora*) in oases of the Baja California peninsula. *Biological Invasions* 12: 3,389–3,393.
- Rodríguez-Revelo N, Espejel I, Jiménez-Orocio O, Martínez ML, Infante-Mata D, Monroy R. 2014a. Baja California. Pp. 146–156 In: *Diagnostico General de las Dunas Costeras de México*. Editors, Martínez ML, Moreno-Casasola P, Espejel I, Jiménez-Orocio O, Infante-Mata D, Rodríguez Revelo N, Cruz-González JC. SEMARNAT, México, DF, Mexico. 350 p.
- Rodríguez-Revelo N, Espejel I, Jiménez-Orocio O, Martínez ML, Infante-Mata D, Monroy R. 2014b. Baja California Sur. Pp. 159–168 In: *Diagnostico General de las Dunas Costeras de México*. Editors, Martínez ML, Moreno-Casasola P, Espejel I, Jiménez-Orocio O, Infante-Mata D, Rodríguez Revelo N, Cruz-González JC. SEMARNAT, México, DF, Mexico. 350 p.
- Romero-Schmidt H, Ortega-Rubio A, Arguelles-Méndez C, Coria-Benet R, Solís-Marin F. 1994. The effect of two years of livestock grazing exclosure upon abundance in a lizard community in Baja California



- Sur, Mexico. *Bulletin of the Chicago Herpetological Society* 29: 245–248.
- Romero-Schmidt HL, Ortega-Rubio A. 1999. Changes in lizard abundance on protected versus grazed desert scrub in Baja California Sur, Mexico. *Brazilian Archives of Biology and Technology* 42: 1–6.
- Rorabaugh JC, Lemos-Espinal JA. 2016. *A Field Guide to the Amphibians and Reptiles of Sonora, Mexico*. ECO Herpetological Publishing and Distribution, Rodeo, New Mexico, USA. 688 p.
- Rotem G, Ziv Y, Giladi I, Bouskila A. 2013. Wheat fields as an ecological trap for reptiles in a semiarid agroecosystem. *Biological Conservation* 167: 349–353.
- Santamaría-del-Angel E, Alvarez-Borrego S, Müller-Karger FE. 1994. Gulf of California biogeographic regions based on coastal zone color scanner imagery. *Journal of Geophysical Research* 99: 7,411–7,414.
- Santos-Barrera G, García A, Calzada-Arciniega RA, Pérez-Cervantes NC, Pacheco-Rodríguez J. 2021. Herpetofauna at risk of extinction: amphibians and reptiles in Mexico, critical areas, and conservation strategies. Pp. 275–288 In: *Imperiled: The Encyclopedia of Conservation*. Editors, DellaSala DA, Goldstein MI. Elsevier, Amsterdam, Netherlands. 2,608 p.
- Schirmel J, Bundschuh M, Entling MH, Kowarik I, Buchholz S. 2016. Impacts of invasive plants on resident animals across ecosystems, taxa, and feeding types: a global assessment. *Global Change Biology* 22: 594–603.
- Schloegel LM, Toledo LF, Longcore JE, Greenspan SE, Vieira CA, Lee M, Zhao S, Wangen SC, Ferreira CM, Hipolito M, et al. 2012. Novel, panzootic, and hybrid genotypes of amphibian chytridiomycosis associated with the bullfrog trade. *Molecular Ecology* 21: 5,162–5,177.
- Schlesinger CA, Kaestli M, Christian KA, Muldoon S. 2020. Response of reptiles to weed-control and native plant restoration in an arid, grass-invaded landscape. *Global Ecology and Conservation* 24: e01325.
- SEMARNAT (Secretaría de Medio Ambiente y Recursos Naturales). 2003. *Evaluación de la Degradación del Suelo Causada por el Hombre en la República Mexicana, Escala 1: 250 000. Memoria Nacional 2001-2002*. Semarnat y CP, México, DF, Mexico. 77 p.
- SEMARNAT (Secretaría de Medio Ambiente y Recursos Naturales). 2010. Norma Oficial Mexicana nom-059-semarnat-2010, Protección ambiental-Especies nativas de México de flora y fauna silvestres-Categorías de riesgo y especificaciones para su inclusión, exclusión o cambio-Lista de especies en riesgo. *Diario Oficial de la Federación*, 30 de Diciembre de 2010. SEMARNAT, México, DF, Mexico.
- SEMARNAT (Secretaría de Medio Ambiente y Recursos Naturales). 2019. Modificación del Anexo Normativo III, Lista de especies en riesgo de la Norma Oficial Mexicana NOM-059-SEMARNAT-2010, Protección ambiental-Especies nativas de México de flora y fauna silvestres-Categorías de riesgo y especificaciones para su inclusión, exclusión o cambio-Lista de especies en riesgo. *Diario Oficial de la Federación*, 14 de Noviembre de 2019. SEMARNAT, México, DF, Mexico.
- Senko J, Koch V, Megill WM, Carthy RR, Templeton RP, Nichols WJ. 2010. Fine scale daily movements and habitat use of East Pacific Green Turtles at a shallow coastal lagoon in Baja California Sur, Mexico. *Journal of Experimental Marine Biology and Ecology* 391: 92–100.
- Shreve F. 1951. Vegetation and flora of the Sonoran Desert. Volume 1. Vegetation. *Carnegie Institute of Washington Publications* 591: 1–192.
- Shreve F, Wiggins IR. 1964. *Vegetation and Flora of the Sonoran Desert. 2 Volumes*. Stanford University Press, Stanford, California, USA. 1,752 p.
- Sinervo B, Méndez-de la Cruz F, Miles DB, Heulin B, Bastiaans E, Villagrán-Santa Cruz M, Lara-Resendiz R, Martínez-Méndez N, Calderón-Espinosa MI, Meza-Lázaro RN, et al. 2010. Erosion of lizard diversity by climate change and altered thermal niches. *Science* 328: 894–899.
- Skerratt LF, Berger L, Speare R, Cashins S, McDonald KR, Phillott AD, Hines HB, Kenyon N. 2007. Spread of chytridiomycosis has caused the rapid global decline and extinction of frogs. *EcoHealth* 4: 125–134.
- Smalling KL, Rowe JC, Pearl CA, Iwanowicz LR, Givens CE, Anderson CW, McCreary B, Adams MJ. 2021. Monitoring wetland water quality related to livestock grazing in amphibian habitats. *Environmental Monitoring and Assessment* 193: 58.
- Sokal RR, Michener CD. 1958. A statistical method for evaluating systematic relationships. *University of Kansas Science Bulletin* 38: 1,409–1,438.
- Spencer JE, Pearthree PA. 2001. Headward erosion versus closed-basin spillover as alternative causes of Neogene capture of the ancestral Colorado River by the Gulf of California. Pp. 215–219 In: *The Colorado River: Origin and Evolution: Grand Canyon, Arizona. Grand Canyon Association Monograph 12*. Editors, Young RA, Spamer EE. Grand Canyon Association, Grand Canyon, Arizona, USA. 280 p.
- Terán-Juárez SA, García-Padilla E, Mata-Silva V, Johnson JD, Wilson LD. 2016. The herpetofauna of Tamaulipas, Mexico: composition, distribution, and conservation. *Mesoamerican Herpetology* 3: 42–113.
- Torres-Hernández LA, Ramírez-Bautista A, Cruz-Elizalde R, Hernández-Salinas U, Berriozabal-Islas C, DeSantis DL, Johnson JD, Rocha A, García-Padilla E, Mata-Silva V, et al. 2021. The herpetofauna of Veracruz, Mexico: composition, distribution, and conservation status. *Amphibian & Reptile*

- Conservation* 15(2) [General Section]: 72–155 (e285).
- Troyo-Diéguez E, Cruz-Falcón A, Norzagaray-Campos M, Beltrán-Morales LF, Murillo-Amador B, Beltrán-Morales FA, García-Hernández JL, Valdez-Cepeda RD. 2010. Agotamiento hidro-agricola a partir de la revolucion verde: axtraccion de agua y gestion de la tecnologia de riego en Baja California Sur, México. *Estudios Sociales* 18: 178–201.
- Ureta C, Cuervo-Robayo AP, Calixto-Pérez E. 2018. A first approach to evaluate the vulnerability of islands' vertebrates to climate change in Mexico. *Atmósfera* 31: 221–254.
- Valdez-Villavicencio JH, Peralta-García A, Guillen-González JA. 2016. Nueva población de la tortuga de poza del suroeste *Emys pallida* en el Desierto Central de Baja California, México. *Revista Mexicana de Biodiversidad* 87: 264–266.
- Valdez-Villavicencio JH, Peralta-García A, González-Gutiérrez NS, Hernández-Morlán XI, Hinojosa-Huerta O. 2021. Diversity of the herpetofauna in restored and disturbed sites in the Colorado River Delta, Baja California, Mexico. *Revista Mexicana de Biodiversidad* 92: e923763.
- Valdez-Villavicencio JH, Peralta-García A, Galina-Tessaro P, Hollingsworth BD, Fisher RN. 2023. Distribution and conservation of the southwestern pond turtle *Actinemys pallida* in Baja California, México. Pp. 69–79 In: *Estudios Sobre la Biología y Conservación de las Tortugas en México. Revista Latinoamericana de Herpetología, Publicación Especial #6*. Editors, Macip-Ríos R, Flores-Villela O. Sociedad Herpetológica Mexicana, México, DF, Mexico. [In Press].
- Valentine LE, Roberts B, Schwarzkopf L. 2007. Mechanisms driving avoidance of non-native plants by lizards. *Journal of Applied Ecology* 44: 228–237.
- Vanderplank S, Ezcurra E, Delgadillo J, Felger R, McDade LA. 2014a. Conservation challenges in a threatened hotspot: agriculture and plant biodiversity losses in Baja California, Mexico. *Biodiversity and Conservation* 23: 2,173–2,182.
- Vanderplank S, Wilder BT, Ezcurra E. 2014b. *Uncovering the Dryland Biodiversity of the Cabo Pulmo Region*. Botanical Research Institute of Texas and Next Generation Sonoran Desert Researchers, Fort Worth, Texas, USA. 107 p.
- Van Devender T. 1990. Late Quaternary vegetation and climate of the Sonoran Desert, United States, and Mexico. Pp. 134–165 In: *Packrat Middens: The Last 40,000 Years of Biotic Change*. Editors, Betancourt JL, Van Devender TR, Martin PS. University of Arizona Press, Tucson, Arizona, USA. 478 p.
- Wake DB. 1991. Declining amphibian populations. *Science* 253: 860.
- Wiggins IL. 1980. *Flora of Baja California*. Stanford University Press, Stanford, California, USA. 1,025 p.
- Wilson LD, Mata-Silva V, Johnson JD. 2013a. A conservation reassessment of the reptiles of Mexico based on the EVS measure. Contribution to Special Mexico Issue. *Amphibian & Reptile Conservation* 7(1): 1–47 (e61).
- Wilson LD, Johnson JD, Mata-Silva V. 2013b. A conservation reassessment of the amphibians of Mexico based on the EVS measure. Contribution to Special Mexico Issue. *Amphibian & Reptile Conservation* 7(1): 97–127 (e69).
- Wilson LD, Johnson JD, Porras LW, Mata-Silva V, Elí García-Padilla E. 2017. A system for categorizing the distribution of the Mesoamerican herpetofauna. *Mesoamerican Herpetology* 4: 901–913.
- Wilson LD, McCranie JR. 2004. The conservation status of the herpetofauna of Honduras. *Amphibian & Reptile Conservation* 3(1): 6–33 (e12).
- Woolrich-Piña GA, Ramírez-Silva JP, Loc-Barragán J, Ponce Campos P, Mata-Silva V, Johnson JD, García-Padilla E, Wilson LD. 2016. The herpetofauna of Nayarit, Mexico: composition, distribution, and conservation status. *Mesoamerican Herpetology* 3: 375–448.
- Woolrich-Piña GA, García-Padilla E, DeSantis DL, Johnson JD, Mata-Silva V, Wilson LD. 2017. The herpetofauna of Puebla, Mexico: composition, distribution, and conservation status. *Mesoamerican Herpetology* 4: 790–884.

## The herpetofauna of the Baja California Peninsula



**Anny Peralta-García** is a biologist from Ensenada, Baja California. She earned her Master's degree at San Diego State University (California, USA) and her Ph.D. at CIBNOR in Baja California Sur (Mexico). Her research interests include habitat restoration and the conservation of amphibians and reptiles in northwestern Mexico. She has authored several research articles, natural history notes, and two field guides on the Baja California Pacific islands. Anny is a board member of the Mexican Herpetology Society and is co-founder of Fauna del Noroeste, a non-profit organization that seeks to promote local biodiversity conservation based on scientific research. Through her organization, she has helped to recover Baja California populations of the California Red-legged Frog. She has collaborated on re-introducing this species into southern California, where it had been extirpated for over 20 years. One of her dreams is to restore freshwater wetlands in Baja California. Anny loves collaborating with anyone willing to help conserve biodiversity and promote research in under-represented species.



**Jorge H. Valdez-Villavicencio** was born in Ensenada, Baja California, Mexico. He obtained his Bachelor's degree at the Universidad Autónoma de Baja California (UABC), and his Master's degree in the use, management, and conservation of natural resources at the Centro de Investigaciones Biológicas del Noroeste in La Paz, Baja California Sur. He has collaborated on various projects related to the monitoring, research, and conservation of wildlife, mainly amphibians and reptiles in the Baja California peninsula. Jorge is an Associated Curator of the Herpetological Collection of the UABC, and the San Diego Natural History Museum. An author or co-author of several scientific papers, Jorge has participated in national and international scientific meetings, symposia, and workshops, and is a member of the two Mexican herpetological societies. Currently, he is the Research Coordinator and founding member of Fauna del Noroeste, a non-profit organization that seeks to promote local biodiversity conservation based on scientific research. His research interest is focused on the ecology and conservation of amphibians and reptiles.

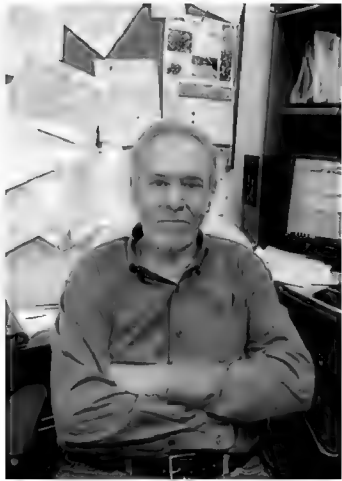


**Lydia Allison Fuesko**, who resides in Melbourne, Australia, is an environmental activist and amphibian conservationist. As a photographer with international publications, she has taken countless amphibian photographs, including photo galleries of frogs mostly from southeastern Australia. Lydia has a Bachelor of Humanities from La Trobe University (Bundoora, Victoria, Australia), a Diploma in Education from the University of Melbourne (Parkville, Victoria, Australia), and postgraduate diplomas in computer education and in vocational education and training from the University of Melbourne (Parkville). Additionally, she has a Master's Degree in Counseling from Monash University (Clayton, Victoria, Australia). She received her Ph.D. on Environmental Education, which promoted habitat conservation, species perpetuation, and global sustainable management, from Swinburne University of Technology (Hawthorn, Victoria, Australia), while being mentored by the late Australian herpetologist and scholar Dr. Michael James Tyler (Order of Australia recipient). A sought-after educational consultant, Lydia has academic interests that include: clinical psychology, focusing on psychopathology; neuroscience and empathy; environmental education for sustainable development; sentient ecology; academic writing; and creative writing, which includes poetry and creative non-fiction books for children and young adults. Lydia is also the senior author (with Boria Sax) of a chapter in the 2019 *Springer Encyclopedia of Sustainability in Higher Education* entitled "Learning Activities for Environmental Education for Sustainable Development." Recently, she co-authored an obituary of Jaime D. Villa; a study of the introduced Mesoamerican herpetofauna; a treatment of conservation prospects of the Mesoamerican salamander fauna; papers on the herpetofaunas of Veracruz, Querétaro, and Guanajuato, Mexico; reviews of the books *Advances in Coralsnake Biology, with an Emphasis on South America and Lizards of Mexico. Part 1: Iguanian Lizards*; a study on the biological and cultural diversity of Oaxaca, Mexico; the description of a new species of snake named *Tantilla carolina* in honor of her mother Karolina Laszló; and a survey co-authored with Michael J. Tyler of calamities affecting museum collections around the world, among several other academic papers. In 2020, the species *Tantilla lydia*, with the suggested common name of Lydia's little snake, was named in her honor.





**Bradford Hollingsworth** has had a life-long interest in the diversity of amphibians and reptiles. His research focuses on the systematics and biogeography of amphibians and reptiles of the Southwest, including the Baja California peninsula and its associated islands. He is responsible for the care and maintenance of San Diego Natural History Museum's 78,000 amphibian and reptile research specimens, as the newly-established Laurence M. Klauber Curator of Herpetology, and launched the *Amphibian and Reptile Atlas of Peninsular California* to help make biodiversity information more accessible to the world. Bradford received his B.S. (1988) and M.S. (1995) degrees from San Diego State University, and his doctorate (1999) from Loma Linda University (Loma Linda, California, USA).



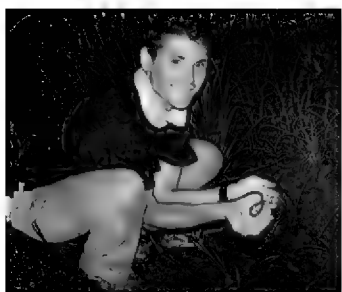
**Jerry D. Johnson** is Professor of Biological Sciences at The University of Texas at El Paso, and has extensive experience studying the herpetofauna of Mesoamerica, especially that of southern Mexico. Jerry is the Director of the 40,000-acre "Indio Mountains Research Station," was a co-editor on *Conservation of Mesoamerican Amphibians and Reptiles* and co-author of four of its chapters. He is also the senior author of the recent paper "A conservation reassessment of the Central American herpetofauna based on the EVS measure" and is Mesoamerica/Caribbean editor for Geographic Distribution section of *Herpetological Review*. Johnson has authored or co-authored over 130 peer-reviewed papers, including two notable articles in 2010, "Geographic distribution and conservation of the herpetofauna of southeastern Mexico" and "Distributional patterns of the herpetofauna of Mesoamerica, a Biodiversity Hotspot." One species, *Tantilla johnsoni*, has been named in his honor. Presently, he is an Associate Editor and Co-chair of the Taxonomic Board for the journal *Mesoamerican Herpetology*.



**Vicente Mata-Silva** is a herpetologist originally from Río Grande, Oaxaca, Mexico. His interests include the ecology, conservation, behavior, systematics, natural history, and biogeography of the herpetofaunas of Mexico, Central America, and the southwestern United States. He received his B.S. degree from the Universidad Nacional Autónoma de México (UNAM), and his M.S. and Ph.D. degrees from the University of Texas at El Paso (UTEP). Vicente is an Assistant Professor of Biological Sciences at UTEP in the Ecology and Evolutionary Biology Program, and Assistant Director of UTEP's 41,200-acre Indio Mountains Research Station, located in the Chihuahuan Desert of Trans-Pecos, Texas. To date, Vicente has authored or co-authored over 100 peer-reviewed scientific publications. He also is a Taxonomic Board Member of the website *Mesoamerican Herpetology* and Associate Editor for the journal *Herpetological Review*.



**Arturo Rocha** is a Ph.D. student in the Ecology and Evolutionary Biology program at the University of Texas at El Paso. His interests include the study of the biogeography, physiology, and ecology of amphibians and reptiles in the southwestern United States and Mexico. A graduate of the University of Texas at El Paso, his thesis centered on the spatial ecology of the Trans-Pecos Rat Snake (*Bogertophis subocularis*) in the northern Chihuahuan Desert. To date, he has authored or co-authored over 20 peer-reviewed scientific publications.



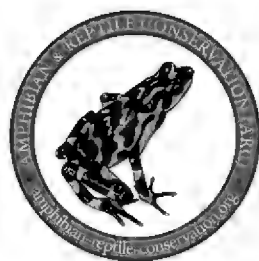
**Dominic L. DeSantis** is an Assistant Professor of Biology at Georgia College & State University, Milledgeville, Georgia, USA, in the Department of Biological and Environmental Sciences. Dominic's research interests broadly include the behavioral ecology, conservation biology, and natural history of herpetofauna. In addition to ongoing collaborative projects associated with the Mesoamerican Research Group, much of Dominic's current research focuses on using animal-borne sensor technologies to study the behavioral ecology of snakes in the field. While completing his Ph.D. at the University of Texas at El Paso, Dominic accompanied Vicente Mata-Silva, Elí García-Padilla, and Larry David Wilson on survey and collecting expeditions to Oaxaca in 2015, 2016, and 2017, and is a co-author on numerous natural history publications produced from those visits, including an invited book chapter on the conservation outlook for herpetofauna in the Sierra Madre del Sur of Oaxaca.



**Louis W. Porras** graduated with a degree in Biology in 1971 from what is known today as Miami-Dade College (Miami, Florida, USA). Over his career, Louis has authored or co-authored over 60 academic publications, including the descriptions of two new species, and two taxa have been named in his honor. Louis developed an interest in herpetology at an early age in his native Costa Rica. His passion for the field led him to travel to many remote areas, including throughout the Bahamas, the United States, Mesoamerica, and parts of South America. In 1968, he worked at the Houston Zoological Gardens, and from 1982 to 1984 at Utah's Hogle Zoo. In 1976, he attended the inaugural meeting of the International Herpetological Symposium (IHS), and later served the group as Vice-President and President. In 1993, along with Gordon W. Schuett, he helped launch the journal *Herpetological Natural History*, and for the IHS' 20<sup>th</sup> anniversary, in recognition of his contributions, three former Presidents dedicated the book *Advances in Herpetoculture* in his honor. Louis' career in publishing began in 1995, when as a member of Canyonlands Publishing Group, he helped publish *Fauna* magazine and the book *Pythons of Australia*. In 2002, he founded Eagle Mountain Publishing, LC, which has published such herpetological titles as *Biology of the Vipers* (2002), *Biology of the Boas and Pythons* (2007), *Amphibians, Reptiles, and Turtles in Kansas* (2010), *Conservation of Mesoamerican Amphibians and Reptiles* (2010), and *Amphibians and Reptiles of San Luis Potosí* (2013). From 2014 to 2018, he was the Publisher and Managing Editor of the journal *Mesoamerican Herpetology*, and more recently he was the Publisher and Co-editor of the book *Advances in Coralsnake Biology: with an Emphasis on South America*.



**Larry David Wilson** is a herpetologist with extensive experience in Mesoamerica (1966 to the present). He was born in Taylorville, Illinois, United States, and received his university education at the University of Illinois at Champaign-Urbana (B.S. degree, 1962) and at Louisiana State University in Baton Rouge (M.S. and Ph.D. degrees, 1965 and 1968, respectively). He has authored or co-authored 482 peer-reviewed papers and books on herpetology. Larry is the senior editor of *Conservation of Mesoamerican Amphibians and Reptiles* (2010) and the co-author of seven of its chapters. His other books, all co-authored, include *The Snakes of Honduras* (two editions, 1982 and 1985), *Middle American Herpetology* (1988), *The Amphibians of Honduras* (2002), *Amphibians & Reptiles of the Bay Islands and Cayos Cochinos, Honduras* (2005), *The Amphibians and Reptiles of the Honduran Mosquitia* (2006), and *Guide to the Amphibians & Reptiles of Cusuco National Park, Honduras* (2008). He is also the co-author of 15 published entries in the Mexican Conservation Series dealing with the herpetofauna of the states of Michoacán, Oaxaca, Chiapas, Tamaulipas, Nayarit, Nuevo León, Jalisco, Puebla, Coahuila, Hidalgo, Veracruz, Querétaro, Tabasco, and Guanajuato, as well as the tri-state Mexican Yucatan Peninsula. In addition, Larry is a co-author of several significant publications on the development and extensive application of the EVS measure and on conservation issues related to the Mexican herpetofauna at the national level. To date, he has authored or co-authored the descriptions of 76 currently-recognized herpetofaunal species, and six species have been named in his honor, including the anuran *Craugastor lauraster*, the lizard *Norops wilsoni*, and the snakes *Oxybelis wilsoni*, *Myriopholis wilsoni*, and *Cerrophidion wilsoni*, as well as the coccidian parasite *Isospora wilsoni*. In 2005, he was designated a Distinguished Scholar in the Field of Herpetology at the Kendall Campus of Miami-Dade College by the then-campus president, Dr. Wasim Shomar. Currently, Larry is a Co-chair of the Taxonomic Board for the website *Mesoamerican Herpetology*.



urn:lsid:zoobank.org:pub:737F8861-364F-48EC-8DCD-BBDCAD3573C4

# A new species of salamander (Caudata: Plethodontidae: *Bolitoglossa*) from the subalpine rain páramo of the Cordillera de Talamanca, Costa Rica

<sup>1,2,3,\*</sup>Erick Arias, <sup>3</sup>Gerardo Chaves, and <sup>1</sup>Gabriela Parra-Olea

<sup>1</sup>Departamento de Zoología, Instituto de Biología, UNAM, AP 70-153 Ciudad Universitaria, CP 04510, México, D.F., MEXICO <sup>2</sup>Escuela de Biología, Universidad de Costa Rica, San Pedro, 11501-2060 San José, COSTA RICA <sup>3</sup>Centro de Investigaciones en Biodiversidad y Ecología Tropical (Museo de Zoología), Universidad de Costa Rica, San Pedro, 11501-2060 San José, COSTA RICA

**Abstract.**—The subalpine rain páramo of Isthmian Central America is an area with a high level of endemism. The salamanders of the *Bolitoglossa subpalmata* Species Group are restricted to the highlands of Costa Rica and Panama, including the subalpine rain páramo. During explorations of the páramos in the Cordillera de Talamanca, we found populations of *Bolitoglossa* that were referred to *B. subpalmata* S.G. These new populations were compared phylogenetically with all species within the species group using the 16S and cyt *b* mitochondrial genes; and they were also compared morphometrically with *B. kamuk* and *B. pesrubra*. Herein we described a new species of the *B. subpalmata* Species Group, which inhabits the subalpine rain páramo and montane forest surrounding the páramo in the Southeastern region in Costa Rica. This new species highlights the role of the subalpine rain páramo in the speciation of salamanders in the highlands of Isthmian Central America, as well as the need to protect this unique and vulnerable habitat.

**Keywords.** Amphibia, caudate, Central America, páramo, phylogenetics, Plethodontidae

**Resumen.**—El páramo subalpino de América Central Ístmica es alto en endemismos. Las salamandras del grupo de especies *Bolitoglossa subpalmata* están restringidas a las tierras altas de Costa Rica y Panamá, incluyendo el páramo subalpino. Durante exploraciones a los páramos en la Cordillera de Talamanca encontramos varias poblaciones de *Bolitoglossa* que fueron asignadas al grupo de especies *B. subpalmata*. Estas nuevas poblaciones fueron comparadas filogenéticamente con todas las especies dentro del grupo de especies de *B. subpalmata*; además fueron comparadas morfométricamente contra *B. kamuk* y *B. pesrubra*. Aquí se describe una nueva especie del grupo de especies *B. subpalmata*, habitante del páramo subalpino y del bosque montano cerca del páramo en la región sureste de Costa Rica. Esta nueva especie resalta el rol del páramo subalpino en la especiación de las salamandras de las tierras altas de América Central Ístmica y la necesidad de proteger este hábitat único y vulnerable.

**Palabras clave.** América Central, Amphibia, Caudados, filogenética, Páramo, Pletodontidae

**Citation:** Arias E, Chaves G, Parra-Olea G. 2023. A new species of salamander (Caudata: Plethodontidae: *Bolitoglossa*) from the subalpine rain páramo of the Cordillera de Talamanca, Costa Rica. *Amphibian & Reptile Conservation* 17(1 & 2): 143–160 (e327).

**Copyright:** © 2023 Arias et al. This is an open access article distributed under the terms of the Creative Commons Attribution License [Attribution 4.0 International (CC BY 4.0): <https://creativecommons.org/licenses/by/4.0/>], which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited. The official and authorized publication credit sources, which will be duly enforced, are as follows: official journal title *Amphibian & Reptile Conservation*; official journal website: [amphibian-reptile-conservation.org](http://amphibian-reptile-conservation.org).

**Accepted:** 5 November 2023; **Published:** 24 December 2023

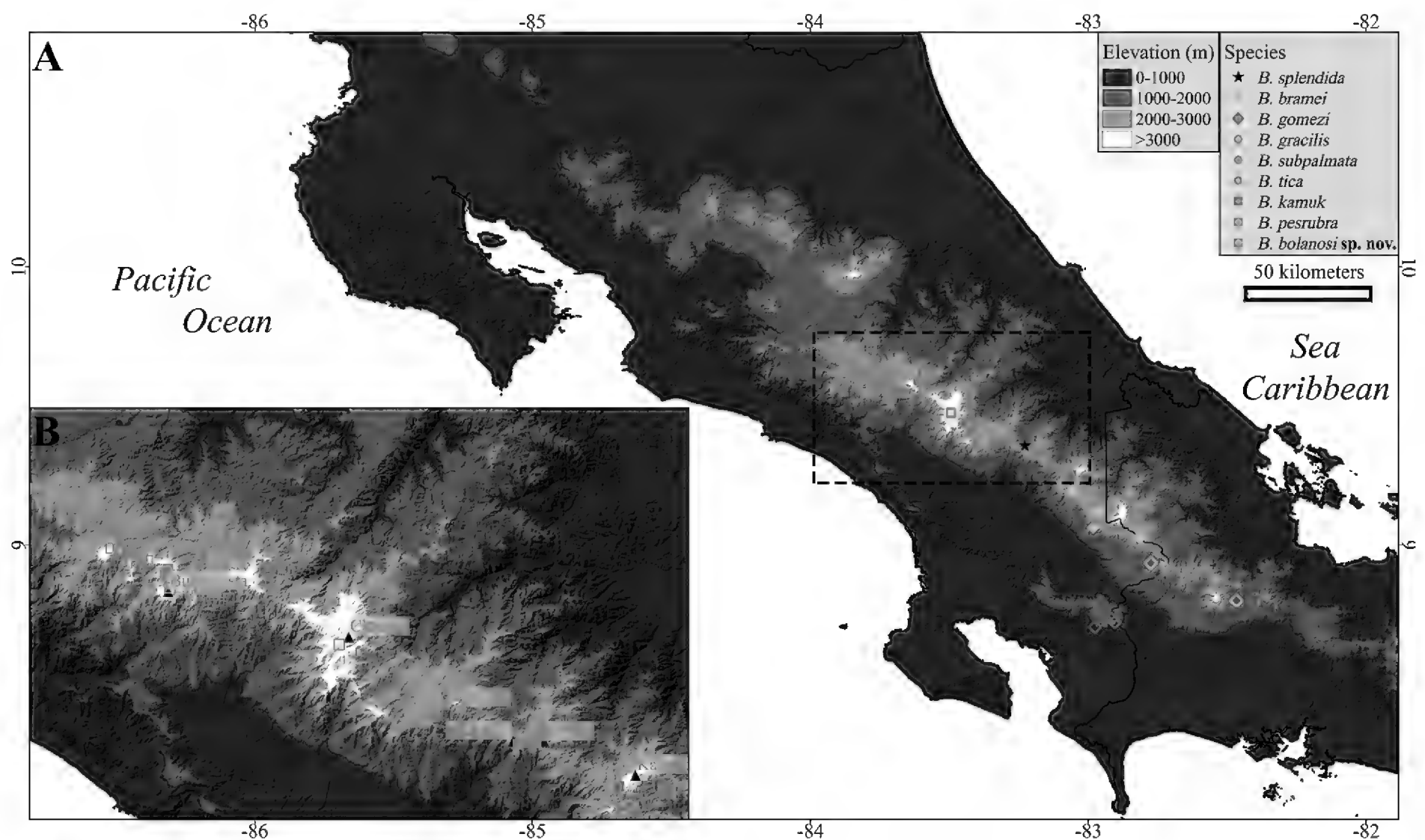
## Introduction

The subalpine rain páramo from Isthmian Central America (ICA) is an extremely reduced ecosystem that is fragmented and vulnerable. In ICA, the subalpine rain páramo is isolated in the highlands, especially in the Cordillera de Talamanca's summits, and covers less than 150 km<sup>2</sup> (Kappelle and Horn 2016). The páramo in ICA can

be considered a “sky island” located in the northwestern part of the Neotropical páramo, separated by straight-line distances of 1,100 km to Colombia's Páramo and 1,000 km to the highlands of Nuclear Central America. The subalpine páramo of ICA is characterized by low species diversity but a high level of endemism, especially among plants, although several vertebrate species are exclusive to the páramo (Kappelle and Horn 2016). Even though

**Correspondence.** \*[eapiedra@gmail.com](mailto:eapiedra@gmail.com)





**Fig. 1.** (A) Map showing the known populations of the species within the *Bolitoglossa subpalmata* species group. (B) Map showing the localities for *B. bolanosi* sp. nov. and the species close to it in the páramo of the Cordillera de Talamanca. The open shapes indicate the historical data and the solid shapes indicate the localities with molecular data included herein.

the subalpine rain páramo of ICA is relatively small in area, several regions remain unexplored and several species may possibly remain unnamed. To the best of our knowledge, only three species of salamanders are exclusively found in the ICA's páramo: *Bolitoglossa kamuk*, *B. pesrubra*, and *B. pygmaea*.

Most salamanders of the ICA are associated with the highlands, especially on the Cordillera de Talamanca, where studies have documented high species turnover between sites and along elevational gradients (García-Paris et al. 2000; Wake 1987). The *Bolitoglossa subpalmata* Species Group (Parra-Olea et al. 2004) is an example of this pattern, containing eight species (*B. bramei*, *B. gomezi*, *B. gracilis*, *B. kamuk*, *B. pesrubra*, *B. splendida*, *B. subpalmata*, and *B. tica*) that are distributed in the highlands of Costa Rica and western Panama (Fig. 1), with high species turnover along latitudinal and elevational gradients (AmphibiaWeb 2023; Boza-Oviedo et al. 2012; García-Paris et al. 2008). Although the phylogenetic relationships of the *Bolitoglossa subpalmata* S.G. have been relatively well-studied (Boza-Oviedo et al. 2012), there is still little information on the distribution ranges of the species in this group, especially *B. pesrubra*, and the area between the páramo of the Cerro Chirripó and the páramo of the Cerro Kamuk has not been sampled at all.

During fieldwork in the subalpine rain páramo in the Cordillera de Talamanca, specifically the summits of the peaks Dúrika, Arbolado, Hakú, and Utyum (Fig. 1), we found some specimens of the *B. subpalmata* S.G., filling in the distribution range for the group. Based on the molecular and morphological data reported herein, we

describe these samples as a new species of *Bolitoglossa* closely related to *B. kamuk* and *B. pesrubra* of the *B. subpalmata* S.G.

## Materials and Methods

**Taxon sampling.** In July 2013, March 2015, January 2016, and October 2016, we carried out collecting trips to Cerro Utyum (July 2013 and March 2015), Cerro Dúrika (January 2016), Cerro Arbolado (October 2016), and Cerro Hakú (October 2016) on the Talamanca Mountain range within La Amistad International Park, Costa Rica (Fig. 1). These trips involved walking a transect from Olán, Buenos Aires (9.2788° N, 83.2156° W, 1,500 m asl; all GPS coordinates in WGS84 datum) on the Pacific slope to the summits of the peaks. The salamanders were found by opening bromeliads from previously cut-off trees, and a total of 19 specimens referred to *Bolitoglossa subpalmata* S.G. were found in the sampled peak summits.

All the specimens collected for this study were humanely euthanized using a topical anesthetic. Following the euthanization process, a small tissue sample, either liver or the tip of the tail, was taken and stored in 96% ethanol. The specimens were fixed in a 10% formalin solution and transferred to 70% ethanol for long-term preservation. Individuals were deposited in the herpetological collection of Museo de Zoología at Universidad de Costa Rica (UCR) (Appendix 1). Museum collection acronyms follow Frost (2023), with the additions of EAP (Erick Arias field numbers), CRARC (Costa Rica Amphibian Research Center private

collection), and NV= No voucher.

**Amplification and sequencing.** Total genomic DNA was extracted from the ethanol-preserved tissues of 24 *Bolitoglossa* specimens using the phenol-chloroform standard protocol (Sambrook and Russell 2006). The large subunit ribosomal RNA (16S) and cytochrome *b* (cyt *b*) mitochondrial genes were amplified. The primers 16Sar and 16Sbr (Palumbi et al. 1991) were used for 16S, and primers MVZ15 and MVZ16 (Moritz et al. 1992) were used for cyt *b*. PCR amplifications were performed using a total volume of 15  $\mu$ L, which contained 1  $\mu$ L DNA template (at 50 ng  $\mu$ L<sup>-1</sup>), 0.75 U Taq polymerase (Amplificasa®, Biotecnologías Moleculares), 1X PCR buffer with 1.5 mM MgCl<sub>2</sub>, 0.2 mM deoxynucleotide triphosphates (dNTPs), and 0.3  $\mu$ M forward and reverse primers. The PCR conditions were as follows: for 16S, an initial cycle of 5 min at 94 °C, followed by 35 cycles of 45 s at 94 °C, 30 s at 55 °C, 45 s at 72 °C, plus a final step of 3 min at 72 °C; and for cyt *b*, an initial cycle of 2 min at 94 °C, followed by 38 cycles of 30 s at 94 °C, 1 min at 48 °C, 1 min at 72 °C, plus a final step of 8 min at 72 °C. The PCR products were cleaned with ExoSap-IT (USB Corporation) and sequenced in both directions using the original amplification primers and BigDye termination reaction chemistry (Applied Biosystems). The cycle-sequencing products were column-purified with Sephadex G-50 (GE Healthcare) and run on an ABI 3500xL Genetic Analyzer (Applied Biosystems). Consensus sequences for each individual were constructed using SEQUENCHER 5.3 (Genes Codes Corp.). The resulting sequences were deposited in GenBank (Appendix 1).

**Phylogenetic analyses.** The sequences obtained here were compared with the sequences of the 16S and cyt *b* mitochondrial genes for 78 specimens of the *Bolitoglossa subpalmata* species group. Sequences of *B. aurae* were used as outgroup and those from *B. compacta* were used to root all trees based on the results in Rovito et al. (2015). The list of vouchers and GenBank accession numbers used in this study are provided in Appendix 1. Sequence alignments were performed using the MUSCLE 3.7 software (Edgar 2004) with default parameters and trimmed to the point where most of the taxa had sequence data. PartitionFinder v2.1.1 software (Lanfear et al. 2017) and the Bayesian Information Criterion (BIC) were used to select the best partition scheme and the best model of sequence evolution for each partition. A single set of *branchlengths* was used across all partitions (*branchlengths*=linked), and the search for the best partition scheme used a heuristic search (*scheme*=greedy, Lanfear et al. 2012). Four subsets were defined *a priori*: one for 16S and three for cyt *b* (partitioned by codon position).

Phylogenetic analyses were performed using both Maximum Likelihood (ML) and Bayesian Inference (BI) methods. The maximum likelihood analysis was performed using Garli 2.01 (Zwickl 2006). To find the best tree, ten search replicates were run with the following default setting values: *streefname* = random, *attachmentsper-taxon* = 24, *genthreshfortopoterm* =

100,000, and *significanttopochange* = 0.00001. For bootstrapping, 1,000 pseudoreplicates were run with the previous settings and with the following changes: *genthreshfortopoterm* = 10,000, *significanttopochange* = 0.01, and *treerejectionthreshold* = 20, as suggested in the Garli manual to speed up the bootstrapping. From these bootstraps, a majority rule consensus tree was obtained using Sumtrees (Sukumaran and Holder 2010a) from DendroPy package version 4.4.0 (Sukumaran and Holder 2010b). Bayesian phylogenetic analysis was performed using MrBayes 3.2.6 (Ronquist et al. 2012) with the partition scheme and the model of sequence evolution for each partition as selected previously. Two separate analyses were run, each consisting of 50 million generations, sampled every 1,000 generations, and four chains with default heating parameters. A time-series plot of the likelihood scores of the cold chain was examined to check stationarity using Tracer 1.6 software (Rambaut et al. 2014). The first 25% of trees were discarded as burn-in and the remaining trees were used to estimate the *allcompat* consensus tree along with the posterior probabilities for each node and each parameter. The Garli and MrBayes analyses were run on the CIPRES portal (Miller et al. 2010). Genetic distances (uncorrected *p*-distances) were computed using MEGA6 (Tamura et al. 2013).

**Morphometrics.** The measurements used herein follow those proposed by Kubicki et al. (2022). The specimens from new localities were compared morphometrically only with the species *B. kamuk* and *B. pesrubra*, given that these are the species of the group that inhabit the subalpine páramo and occur geographically close (Fig. 1, Appendix 2). The following 29 morphological measurements were taken on each of the 31 adult specimens of *Bolitoglossa subpalmata* S.G. that were examined in this study: standard length (SL), shoulder width (ShW), head width (HeW), neck width (NeW), eye width (EW), snout length (SnL), jaw to snout length (JSL), lateral gular fold to tip of snout (LGFS), internarial distance (IND), naris to lip distance (NLP), intercanthal distance (ICD), hind limb length (HLL), front limb length (FLL), trunk width (TW), midventral gular fold to snout length (VGS), front limb to snout distance (FSL), ulna and hand length (UHL), axilla to groin length (AGL), vent length (VL), hand width (HaW), hand length (HaL), length of Finger III (LF3), width of Finger III (WF3), length of Finger II (LF2), foot width (FoW), foot length (FoL), length of Toe III (LT3), width of Toe III (WT3), and length of Toe II (LT2). The additional proportions reported here include: IND/HeW, HeW/AGL, SnL/HeW, HaL/VGS, FoL/VGS, HaW/HeW, FoW/HeW, LT2/FoL, LF2/HaL, WT3/FoW, WF3/HaW, HaL/HaW, and FoL/FoW.

The measurements were taken with a Mitutoyo Absolute 4084 digital caliper, and rounded to the nearest 0.1 mm. Given that there are very significant overlaps in the numbers of teeth found in the different *Bolitoglossa* species known to occur in Costa Rica (Boza-Oviedo et al. 2012; García-París et al. 2008; Savage 2002), the number of teeth in the specimens examined in this study were not counted. We believe that attempting to accurately count

the number of teeth in such small specimens (most of which were fixed with their mouths in a closed position), requires a high-level of invasive manipulation that would most likely cause significant and unnecessary damage to the mouth cavity. The limb interval is equal to the number of costal folds between the tips of the longest digits of the adpressed front and hind limbs, expressed in 0.5 increments (e.g., 4 or 4.5).

**Morphometric statistics.** To avoid allometric effects relative to the differences in the sizes and shapes between species and between individuals, the data were transformed using the method of Lleonart et al. (2000). In this method, a logarithmic transformation of the continuous variables is performed to reduce the extreme values. All transformed variables were used in the allometric transformation by means of the equation:

$$Y_i^* = Y_i \left[ \frac{X_0}{X_i} \right]^b$$

where  $Y^*$  corresponds to the value of each of the dependent variables corrected for size and shape,  $Y_i$  corresponds to the value of each dependent morphometric variable,  $X_0$  is the average of the SL variable for all populations,  $X_i$  is the SL value for each individual, and  $b$  is the regression line intercept with the Y-axis resulting from the regression of each dependent variable with  $X_0$ . The intercept is used as an allometric transformation factor and is unique for each variable.

A discriminant analysis was performed to determine whether the morphometric variables were effective in predicting the species. Only those variables that were different among at least two of the three putative species analyzed were included in the discriminant analysis. The following variables were finally used in the discriminant analysis: HeW, JSL, ICD, HLL, VGS, HaW, HaL, HaL/VGS, FoL/VGS, and HaW/HeW. The discriminant analyses were separated by sex, and were performed using R v3.3.3 (R Development Core Team 2013).

## Results

**Molecular analyses.** The mitochondrial dataset includes samples of all described species in the *Bolitoglossa subpalmata* S.G. The resulting data matrix had a total of 80 sequences (31 salamanders collected in this study and 49 sequences downloaded from Genbank) with a sequence length of 1,334 bp, including gaps, with 527 bp for 16S and 807 for cyt *b*. Three partitions were identified with the following substitution models: HKY+I+G for 16S + cyt *b* codon position 3, HKY+I for codon position 1 of cyt *b*, and TRN+G for cyt *b* codon position 2.

The phylogenies from Garli and MrBayes were relatively discordant in the internal topology within the *B. subpalmata* S.G. (Fig. 2). However, all phylogenetic analyses found the *B. subpalmata* S.G. to be monophyletic, with three internal clades relatively well-supported. The first clade was formed by *B. bramei* and *B. gomezi*, two species that are restricted to premontane and montane forests of the Pacific slope. The second clade was formed by *B. gracilis* sister to *B. tica* + *B.*

*subpalmata*, and these species are distributed in the Volcanic Central Mountain range and the northern part of the Cordillera de Talamanca. Finally, a well-supported clade was formed by *B. kamuk* sister to *B. pesrubra* + unnamed taxon, and these three species are restricted to the subalpine rain páramo of the Cordillera de Talamanca. The phylogenetic position of *B. splendida* is uncertain. In the Bayesian analysis, this species was weakly supported as sister to the clade formed by the three species of the páramo. In the ML analysis, *B. splendida* was weakly supported as sister to the clade formed by *B. bramei* + *B. gomezi*, forming the sister clade to the clade formed by *B. gracilis*, *B. subpalmata*, and *B. tica*.

The mitochondrial genetic distances are shown in Table 1. Genetic distances between the specimens of the unnamed taxon from the subalpine rain páramo and all other members of the *B. subpalmata* species group are 1.45–4.71% for 16S and 5.03–9.09% for cyt *b*.

**Morphometric analyses.** The specimens examined included 13 specimens (8♀ and 5♂) of the unnamed taxon from the subalpine rain páramo, 15 specimens of *B. pesrubra* (7♀ and 8♂), and three specimens of *B. kamuk* (1♀ and 2♂). The morphometric variation between the three species that inhabit the subalpine rain páramo of Costa Rica is shown in Table 2. The discriminant analysis correctly classified 100% of the specimens to the species (Fig. 3) in both sexes, showing a clear separation between the specimens of the new species described below and the specimens of *B. kamuk* and *B. pesrubra*. The ratios HaL/VGS, HaW/HeW, and IND/HeW differed among the three species of the subalpine rain páramo.

## Description of New Species

### *Bolitoglossa bolanosi* sp. nov.

Bolaños' Web-footed Salamander  
(Figs. 4–6)

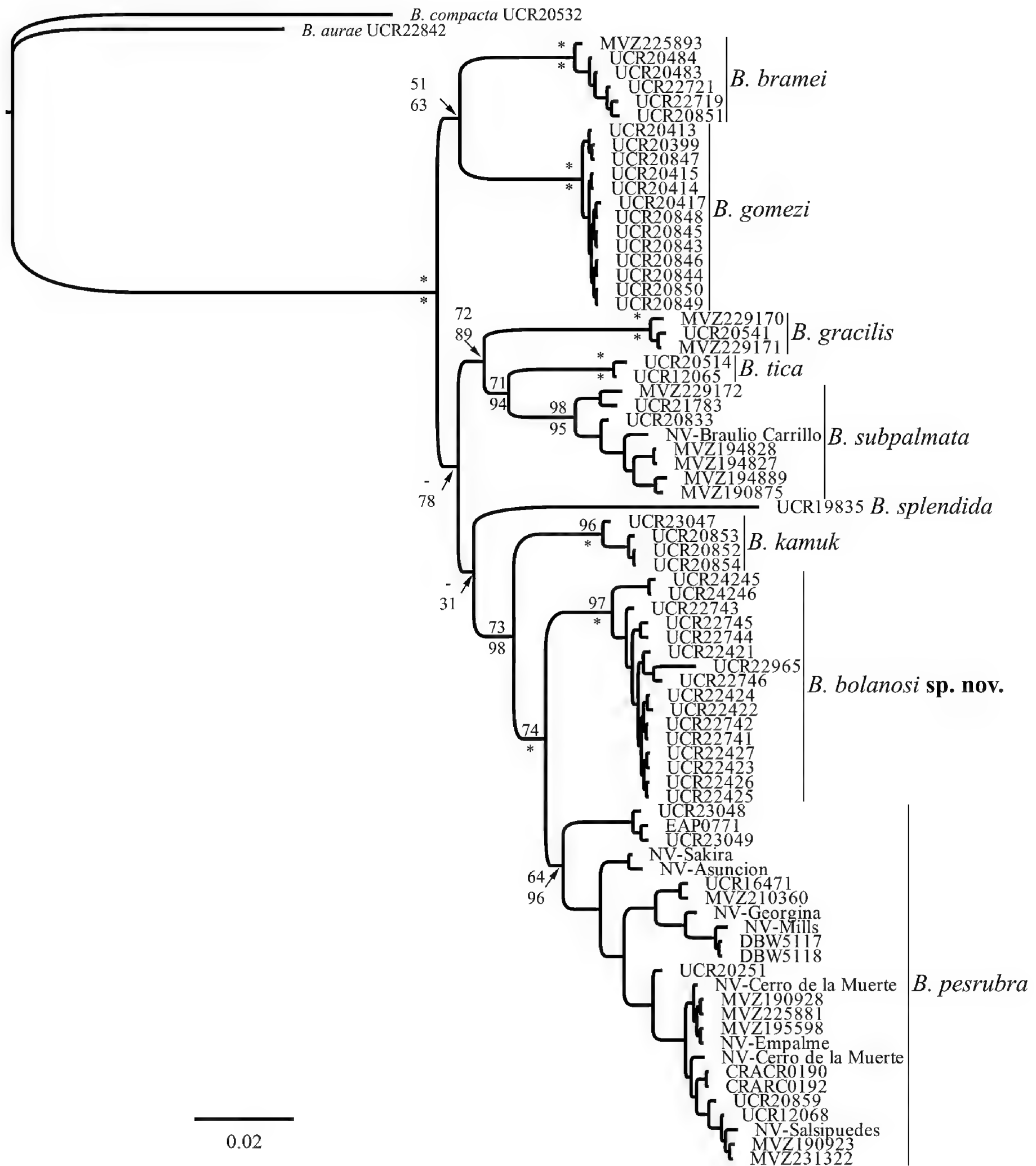
urn:lsid:zoobank.org:act:3F7E0D7E-906F-4FCD-B4CE-0A48F134DEA1

**Holotype.** UCR 22965, an adult male from Costa Rica: Provincia de Puntarenas: Cantón de Buenos Aires: Distrito de Buenos Aires: the summit of Cerro Arbolado, Parque Internacional La Amistad, (9.320°, -83.216°; 2,600 m asl), collected by Erick Arias and Omar Zúñiga on 19 October 2016.

**Paratopotype.** UCR 22964, a subadult male, same data as holotype.

**Paratypes.** UCR 22424, an adult male; UCR 22423, an adult female; UCR 22425, a subadult female; UCR 22422 and UCR 22426, subadult males; and UCR 22427, a juvenile from Costa Rica: Provincia de Puntarenas: Cantón de Buenos Aires: Distrito de Buenos Aires: the summit of Cerro Utyum, Parque Internacional La Amistad, (9.323°, -83.187°; 2,870 m asl), collected by Erick Arias, Gerardo Chaves, Olmer Cordero, and Omar Zúñiga on 30 March 2015. UCR 22421, an adult female from Costa Rica: Provincia de Limón: Cantón de Talamanca: Distrito de Telire: the summit of Cerro Utyum, Parque





**Fig. 2.** Bayesian phylogenetic inference shows the relationships of the *Bolitoglossa subpalmata* species group based on the 16S and cyt *b* mitochondrial DNA gene fragments. Bootstrap proportions from maximum likelihood are shown above the branches, and numbers below the branches are posterior probabilities (multiplied by 100) from the MrBayes analysis. The scale bar refers to the estimated substitutions per site. The support values of any node within the species are not shown. The asterisks represent support >99. NV = no voucher.

Internacional La Amistad, (9.333°, -83.180°; 2,913 m asl), collected by Erick Arias, Gerardo Chaves, Olmer Cordero, and Omar Zúñiga on 30 March 2015. UCR 22745, an adult male; UCR 22741–4, adult females; and UCR 22746, a juvenile from Costa Rica: Provincia de Puntarenas: Cantón de Buenos Aires: Distrito de Buenos Aires: the summit of Cerro Hakú, Parque Internacional La Amistad, (9.322°, -83.203°; 2,660 m asl), collected by Erick Arias and Omar Zúñiga on 28 December 2015.

UCR 24245, an adult female; UCR 24246, an adult male; UCR 24247, a subadult male; and UCR 24248, a juvenile from Costa Rica: Provincia de Puntarenas: Cantón de Buenos Aires: Distrito de Buenos Aires: the summit of Cerro Dúrika, Parque Internacional La Amistad, (9.374°, -83.303°; 3,240 m asl), collected by Omar Zúñiga on 13 January 2016.

**Generic Placement.** Assigned to the genus *Bolitoglossa*

**Table 1.** Mean uncorrected genetic distances, as percentages, among species of the *Bolitoglossa subpalmata* species group, using the 16S (right) and cyt *b* (left) mitochondrial genes.

	<i>B. splendida</i>	<i>B. bramei</i>	<i>B. gomezi</i>	<i>B. gracilis</i>	<i>B. subpalmata</i>	<i>B. tica</i>	<i>B. kamuk</i>	<i>B. pesrubra</i>	<i>B. bolanosi</i> sp. nov.
<i>B. splendida</i>	—	3.88	3.49	4.42	2.63	4.19	2.53	2.74	3.14
<i>B. bramei</i>	10.01	—	3.36	3.20	2.66	3.76	2.32	3.36	3.44
<i>B. gomezi</i>	10.10	5.95	—	4.58	3.09	4.16	2.56	3.60	3.99
<i>B. gracilis</i>	9.30	7.84	7.06	—	2.75	3.73	3.63	4.61	4.71
<i>B. subpalmata</i>	9.53	7.71	6.96	8.12	—	1.94	1.75	2.71	2.82
<i>B. tica</i>	9.47	6.60	6.63	7.29	6.48	—	3.21	3.88	3.39
<i>B. kamuk</i>	10.29	6.56	6.71	7.75	8.46	7.43	—	1.25	1.45
<i>B. pesrubra</i>	9.11	6.51	6.72	7.35	7.78	7.29	7.06	—	1.69
<i>B. bolanosi</i> sp. nov.	9.09	6.50	6.34	7.04	7.57	6.51	5.87	5.03	—

due to having 14 costal grooves and lacking a sublingual fold, and to the subgenus *Eladinea* based on the molecular evidence presented herein.

**Diagnosis.** The combination of the following characteristics can be used to distinguish *Bolitoglossa bolanosi* from the other described species of the genus *Bolitoglossa*: (1) having broad hands and feet, with the distal phalanges on the fingers and toes free of palmar and plantar tissue; (2) dorsal coloration highly variable, rarely black brownish uniform and usually mottled with yellow spots, but never with red on hind limbs or forelimbs; and (3) 16S and cyt *b* mtDNA distances.

**Comparisons.** *Bolitoglossa bolanosi* is differentiated from members of the subgenus *Eladinea* by its 16S and cyt *b* mtDNA distances. Since *B. bolanosi* is only known to occur in Costa Rica and molecular evidence strongly supports it forming part of the *Bolitoglossa subpalmata* species group within the subgenus *Eladinea*, phenotypic comparisons are presented here only concerning the members of that clade (*B. bramei*, *B. gomezi*, *B. gracilis*, *B. kamuk*, *B. pesrubra*, *B. splendida*, *B. subpalmata*, and *B. tica*), which are endemic to mountain ranges of Costa Rica and western Panama.

Contrasting characteristics for *Bolitoglossa bolanosi* are presented in parentheses. *Bolitoglossa bramei* Wake et al., 2007 can be distinguished from *B. bolanosi* by having a rounded snout in males (snout strongly truncated in males); dorsal ground color dark brown to brownish red, usually with darker mottling or frosting of silvery-gray (dorsal ground color black to dark brown, usually with mottling or blotches of yellow to red). *Bolitoglossa gomezi* Wake et al., 2007 has fore limbs relatively shorter, FLL/SL 20% (FLL/SL 22.3–26.1%), snout rounded (snout truncate in males). *Bolitoglossa gracilis* Bolaños et al., 1987 has dorsum yellowish ground color and a distinct dark midventral stripe (dorsum variable but never with yellowish ground color and never with a distinct midventral stripe). *Bolitoglossa splendida* Boza-Oviedo et al., 2012 has a shiny black dorsum with a bright reddish-orange broad dorsal band extending from the back of the head to the base of the tail, and with bright enamel-yellow spots scattered along the lateral and ventrolateral surfaces (dorsum variable but none with a reddish dorsal band extending from the head to the tail). *Bolitoglossa subpalmata* (Boulenger, 1896) has forelimbs that are relatively shorter, FLL/SL 18.7–23.1% (FLL/SL 22.3–26.1%). *Bolitoglossa tica* García-París et al., 2008 has dorsal ground color usually a uniform reddish brown with a darker tail, rarely with mottling or blotches contrasting (dorsal ground color black to dark brown, usually with yellow to red mottling or blotchy contrasting); prominent whitish spots on the venter (venter without whitish spots).

*Bolitoglossa bolanosi* differs from its closest relatives as follows: *Bolitoglossa kamuk* Boza-Oviedo et al., 2012 is smaller and more slender with mean SL 34.6–38.4 mm (larger and robust, SL = 39.43–50.01 mm); internarial distance relatively shorter, IND/HeW = 0.26±0.05 (internarial distance relatively longer, IND/HeW = 0.31±0.05); shorter tail TL/SL 98–99% (tail long, TL/SL

**Table 2.** Morphometric data for *Bolitoglossa bolanosi* sp. nov., *B. kamuk*, and *B. pesrubra*. These data were obtained prior to morphometric correction.

Variable	<i>B. bolanosi</i> sp. nov.		<i>B. kamuk</i>		<i>B. pesrubra</i>	
	Mean±S.D. (Range)		Mean±S.D. (Range)		Mean±S.D. (Range)	
	♀ (N = 8)	♂ (N = 5)	♀ (N = 1)	♂ (N = 2)	♀ (N = 7)	♂ (N = 8)
SL	43.05±5.54 (32.71–50.01)	41.83±6.55 (34.01–49.04)	38.4	35.2±0.85 (34.6–35.8)	50.6±3 (47.6–54.3)	48.34±3.61 (47.6–54.78)
ShW	5.64±0.98 (4.25–7.49)	5.34±1.02 (4.4–7.09)	4.9	3.9±0.14 (3.8–4)	6.3±0.69 (5.2–7.3)	5.46±0.52 (5.2–6.43)
HeW	6.74±0.7 (5.45–7.7)	6.43±0.72 (5.46–7.3)	6	5.15±0.21 (5–5.3)	7.17±0.75 (6.09–8.3)	7.02±0.41 (6.09–7.76)
NeW	5.62±0.84 (3.99–6.72)	5.17±0.74 (4.26–6.17)	5	4.05±0.07 (4–4.1)	6.2±0.77 (5.3–7.4)	5.38±0.52 (5.3–6.53)
EW	2.32±0.28 (1.78–2.59)	2.5±0.48 (2.01–3.18)	2.5	2.15±0.21 (2–2.3)	2.56±0.22 (2.2–2.8)	2.51±0.22 (2.2–2.8)
SnL	2.75±0.32 (2.26–3.09)	2.88±0.43 (2.31–3.43)	2.3	1.95±0.07 (1.9–2)	3.03±0.18 (2.8–3.3)	3±0.76 (2.8–3.78)
JSL	7±0.64 (5.99–8.15)	7±0.88 (6.01–8.21)	6.8	5.95±0.49 (5.6–6.3)	8.09±0.5 (7.6–9)	8.08±0.48 (7.6–8.83)
LGFS	10.99±1.19 (8.46–12.17)	10.75±1.56 (9.06–12.9)	10.2	8.95±0.21 (8.8–9.1)	11.84±0.65 (11.2–12.9)	11.94±0.63 (11.2–12.96)
IND	1.94±0.14 (1.74–2.12)	2.25±0.56 (1.57–3.11)	1.8	1.2	2.27±0.19 (2–2.5)	2.61±0.36 (2–3.16)
NLP	0.9±0.09 (0.74–1.01)	0.87±0.15 (0.74–1.11)	1	0.75±0.07 (0.7–0.8)	1.07±0.13 (0.9–1.3)	1.05±0.16 (0.9–1.28)
ICD	3.3±0.34 (2.88–3.8)	3.27±0.38 (2.93–3.88)	2.8	2.45±0.07 (2.4–2.5)	3.14±0.57 (1.9–3.6)	3.51±0.28 (1.9–3.98)
HLL	11±1.62 (8.03–12.79)	11.07±1.54 (9.47–13.09)	10.4	8.3±0.28 (8.1–8.5)	12.26±0.85 (11.2–13.6)	12.71±1.36 (11.2–14.16)
TW	6.62±1.39 (5.16–9.2)	5.26±0.63 (4.3–6.02)	5.4	3.9±0.14 (3.8–4)	6.93±0.96 (5.8–8.4)	6.1±0.46 (5.8–6.9)
FLL	10.38±1.54 (7.75–11.91)	11.28±3.87 (8.06–17.62)	8.9	8.00	11.27±0.74 (10.1–12.4)	11.51±1.22 (10.1–13.61)
VGS	10.49±1.13 (8.18–11.68)	10.47±1.81 (8.72–13.2)	9.2	8.45±0.35 (8.2–8.7)	11.66±0.52 (11.1–12.4)	11.4±0.56 (11.1–12.2)
FSL	12.75±1.42 (10.16–14.8)	12.59±1.77 (10.91–15.17)	11.9	10.3±0.28 (10.1–10.5)	14.46±0.79 (13.5–15.6)	14.37±0.85 (13.5–15.59)
UHL	7.22±2 (2.63–8.58)	6.51±2.65 (3.2–9.01)	6.5	5.9	8.1±0.64 (7.4–9.4)	6.16±2 (7.4–9.2)
AGL	21.94±3.75 (16.14–26.4)	21.2±3.05 (16.18–24.13)	19.3	17.9±0.28 (17.7–18.1)	27.37±1.89 (25.2–30.1)	24.71±1.96 (25.2–28.35)
VL	4.34±0.7 (3.05–5.09)	4.06±0.85 (2.93–4.94)	4	2.56±0.62 (2.12–3)	4.86±0.53 (4.4–5.8)	4.36±0.64 (4.4–5.78)
HaW	3.66±0.5 (3.04–4.41)	3.79±0.84 (2.68–4.84)	3.3	2.65±0.21 (2.5–2.8)	4.24±0.44 (3.8–5.1)	4.36±0.57 (3.8–5.1)
HaL	3.85±0.64 (2.75–4.64)	3.81±1 (2.91–5.35)	3.7	2.6±0.14 (2.5–2.7)	4.04±0.43 (3.8–5)	4.2±0.49 (3.8–4.9)
WF3	0.86±0.09 (0.73–1.05)	0.79±0.15 (0.59–0.98)	0.9	0.6	0.77±0.08 (0.7–0.9)	0.82±0.11 (0.7–0.99)
LF2	1.61±0.22 (1.33–1.92)	1.81±0.29 (1.59–2.31)	1.6	1.45±0.07 (1.4–1.5)	2.01±0.22 (1.8–2.4)	2.24±0.4 (1.8–2.7)
LF3	2.02±0.25 (1.75–2.39)	2.29±0.45 (1.86–3)	2.3	1.75±0.21 (1.6–1.9)	2.56±0.24 (2.4–3.1)	2.76±0.42 (2.4–3.45)



# A new species of *Bolitoglossa*

**Table 2 (continued).** Morphometric data for *Bolitoglossa bolanosi* **sp. nov.**, *B. kamuk*, and *B. pesrubra*. These data were obtained prior to morphometric correction.

Variable	<i>B. bolanosi</i> <b>sp. nov.</b>		<i>B. kamuk</i>		<i>B. pesrubra</i>	
	Mean±S.D. (Range)		Mean±S.D. (Range)		Mean±S.D. (Range)	
	♀ (N = 8)	♂ (N = 5)	♀ (N = 1)	♂ (N = 2)	♀ (N = 7)	♂ (N = 8)
FoW	4.44±0.76 (3.44–5.42)	4.56±0.87 (3.63–5.74)	3.9	3.45±0.21 (3.3–3.6)	4.96±0.4 (4.5–5.6)	5.17±0.77 (4.5–6.02)
FoL	4.34±0.58 (3.42–5.03)	4.23±0.91 (3.27–5.53)	4.3	3.00	4.6±0.35 (4.1–5.2)	4.78±0.39 (4.1–5.3)
WT3	0.9±0.16 (0.68–1.24)	0.77±0.1 (0.67–0.92)	0.9	0.65±0.07 (0.6–0.7)	0.8±0.1 (0.7–1)	0.86±0.13 (0.7–1.1)
LT2	1.82±0.19 (1.52–2.05)	1.93±0.16 (1.77–2.15)	1.5	1.2±0.14 (1.1–1.3)	2.31±0.22 (2–2.7)	2.44±0.5 (2–3.09)
LT3	2.44±0.44 (1.66–2.94)	2.46±0.22 (2.15–2.68)	2.3	1.65±0.07 (1.6–1.7)	2.79±0.17 (2.6–3)	3.05±0.42 (2.6–3.73)
VGS/SL	0.24±0.01 (0.23–0.26)	0.25±0.01 (0.23–0.27)	0.24	0.24±0 (0.24–0.24)	0.23±0.01 (0.22–0.24)	0.24±0.01 (0.22–0.25)
IND/HEW	0.29±0.02 (0.26–0.32)	0.35±0.05 (0.29–0.43)	0.3	0.23	0.32±0.03 (0.29–0.38)	0.37±0.04 (0.29–0.42)
AGL/SL	0.51±0.03 (0.47–0.58)	0.51±0.05 (0.46–0.58)	0.503	0.51	0.54±0.01 (0.53–0.55)	0.51±0.02 (0.53–0.54)
HEW/SL	0.16±0.01 (0.15–0.17)	0.15±0.01 (0.15–0.17)	0.156	0.15±0.01 (0.14–0.15)	0.14±0.01 (0.12–0.16)	0.15±0.01 (0.12–0.16)
HEW/AGL	0.31±0.03 (0.25–0.36)	0.31±0.02 (0.28–0.34)	0.311	0.29±0.01 (0.28–0.29)	0.26±0.02 (0.23–0.29)	0.28±0.01 (0.23–0.3)
SNL/HEW	0.41±0.04 (0.36–0.45)	0.45±0.03 (0.41–0.48)	0.383	0.38±0.03 (0.36–0.4)	0.42±0.03 (0.37–0.46)	0.43±0.1 (0.37–0.49)
HLL/SL	0.26±0.01 (0.25–0.27)	0.27±0.01 (0.26–0.28)	0.271	0.24±0.01 (0.23–0.24)	0.24±0.01 (0.22–0.26)	0.26±0.02 (0.22–0.3)
FLL/SL	0.24±0.01 (0.22–0.26)	0.26±0.05 (0.23–0.26)	0.232	0.23±0.01 (0.22–0.23)	0.22±0.02 (0.19–0.24)	0.24±0.02 (0.19–0.27)
HAL/VGS	0.37±0.03 (0.33–0.4)	0.36±0.03 (0.33–0.41)	0.402	0.31±0.03 (0.29–0.33)	0.35±0.03 (0.31–0.4)	0.37±0.03 (0.31–0.43)
FOL/VGS	0.41±0.02 (0.37–0.44)	0.4±0.03 (0.37–0.43)	0.467	0.36±0.01 (0.34–0.37)	0.39±0.02 (0.37–0.42)	0.42±0.03 (0.37–0.45)
HAW/HEW	0.54±0.04 (0.48–0.59)	0.58±0.07 (0.49–0.66)	0.55	0.52±0.06 (0.47–0.56)	0.59±0.04 (0.54–0.66)	0.62±0.07 (0.54–0.76)
FOW/HEW	0.66±0.06 (0.55–0.73)	0.7±0.06 (0.64–0.79)	0.65	0.67±0.07 (0.62–0.72)	0.7±0.07 (0.63–0.84)	0.73±0.09 (0.63–0.9)
LT2/HEW	0.27±0.03 (0.24–0.3)	0.31±0.03 (0.26–0.32)	0.25	0.23±0.02 (0.22–0.25)	0.33±0.04 (0.27–0.39)	0.35±0.07 (0.27–0.45)
LT3/FOW	0.55±0.05 (0.48–0.63)	0.56±0.08 (0.47–0.64)	0.59	0.48±0.05 (0.44–0.52)	0.56±0.05 (0.51–0.65)	0.6±0.08 (0.51–0.71)
LT2/FOL	0.42±0.03 (0.37–0.48)	0.47±0.09 (0.35–0.54)	0.349	0.4±0.05 (0.37–0.43)	0.5±0.05 (0.42–0.57)	0.51±0.1 (0.42–0.68)
LF2/HAL	0.43±0.08 (0.29–0.58)	0.49±0.08 (0.42–0.6)	0.432	0.56±0.06 (0.52–0.6)	0.5±0.05 (0.45–0.58)	0.53±0.08 (0.45–0.63)
WT3/FOW	0.2±0.03 (0.16–0.24)	0.17±0.01 (0.16–0.18)	0.231	0.19±0.03 (0.17–0.21)	0.16±0.03 (0.14–0.22)	0.17±0.02 (0.14–0.21)
WF3/HAW	0.24±0.03 (0.21–0.28)	0.21±0.03 (0.16–0.26)	0.273	0.23±0.02 (0.21–0.24)	0.18±0.01 (0.17–0.21)	0.19±0.03 (0.17–0.24)

102.3–117.2%); dorsal ground color relatively uniform, orange to black (dorsal ground usually mottled or blotchy); males with rounded snout (snout strongly truncated in females). *Bolitoglossa pesrubra* (Taylor, 1952) has hands and feet more webbed (Fig. 5C–D), usually less than the ultimate phalange free (with at least the ultimate phalange free beyond the interdigital tissue margin, Fig. 5A–B); has red color on forelimbs and usually on hind limbs (dorsum variable but never with red on hind limbs or forelimbs). Hands relatively wider,  $\text{HaW/HeW} = 0.61 \pm 0.07$  (hands narrower,  $\text{HaW/HeW} = 0.56 \pm 0.06$ ).

**Description of holotype.** Adult male having a SL of 49.05 mm (Fig. 4). Head slightly wider than neck and shoulders (HeW 7.3 mm, NeW 6.2 mm, ShW 7.1 mm), with the greatest width of the head just posterior to the articulation of the jaws; truncate in dorsal outline and rounded to truncate in profile; snout moderate (SnL 3.4 mm, 6.9% of SL), with nearly terminal non-protruding small nostrils (LNH 0.6 mm, RNW 0.4 mm) directed anterolaterally; internarial area convex in dorsal outline. Snout protruding beyond the anterior margin of the lower lip in lateral view. Eyes relatively large ( $\text{EW} = 92\%$  of SnL), weakly protruding beyond the dorsal and ventral outline of the head, directed anterolaterally, with a distinct suborbital groove. Top of head flat and smooth, tapering slightly toward anterior terminus, lacking contrasting interorbital or other dermal structures. Canthus rostralis weakly rounded; intercanthal area flat to slightly convex; and loreal region slightly concave. Evident cirri (nasolabial protuberances) on tip of snout; nasolabial grooves start at ventrolateral margins of nares and terminate in a cirrus. Gular fold is well-defined, starting on the dorsolateral portion of the neck, below the postorbital groove. Evident mental gland is visible under the skin of the anterior intermandibular region.

Arms relatively long and slender (FLL = 12.6 mm, 25.7% of SL), without noticeable hypertrophied forearm compared to the upper arm. Hands well-developed and slender (HaL = 5.4 mm, 40.9% of VGS; HaW = 4.8 mm, 65.8% of HeW). Fingers II, III, and IV protrude freely, with at least the ultimate phalange free beyond interdigital tissue margin (LF2 2.3 mm, LF3 3.0 mm; Fig. 5). Tips of fingers rounded; terminal pads weakly discernible on the ventral surfaces of fingers. Relative lengths of fingers on right hand:  $\text{I} < \text{IV} < \text{II} < \text{III}$ .

Legs moderately long and slender (HLL 13.1 mm, 26.7% of SL). Feet well-developed and slender (FoL 5.5 mm, 41.7% of VGS; FoW 5.7 mm, 78.1% of HeW). Toes II, III, IV, and V protruding freely beyond interdigital tissue margin (LT2 1.9 mm, LT3 2.7 mm), toe I with minimal indentation at interdigital spaces. Toe III is most free of interdigital tissue, with about the entire distal phalanx protruding. Tips of toes rounded; terminal pads weakly discernible on ventral distal surface of toes. Relative lengths of toes on right foot:  $\text{I} < \text{V} < \text{II} < \text{IV} < \text{III}$ .

Body subcylindrical (slightly wider than high) in cross-section, and relatively slender (TW = 6.0 mm;  $\text{TW} = 26.5\%$  of AGL). Between the axilla and groin, 11 costal grooves are visible, 13 if counting axillary and inguinal grooves; costal grooves are most visible on ventral and

lateral portions of the body. Adpressed limbs separated by one costal fold; 12 costal folds total between axilla and groin. The tail is long, cylindrical in cross-section, with an evident constriction at the base, and some caudal grooves discernible on the anterior portion of the tail. The skin on the surfaces of the head, body, limbs, and tail is smooth.

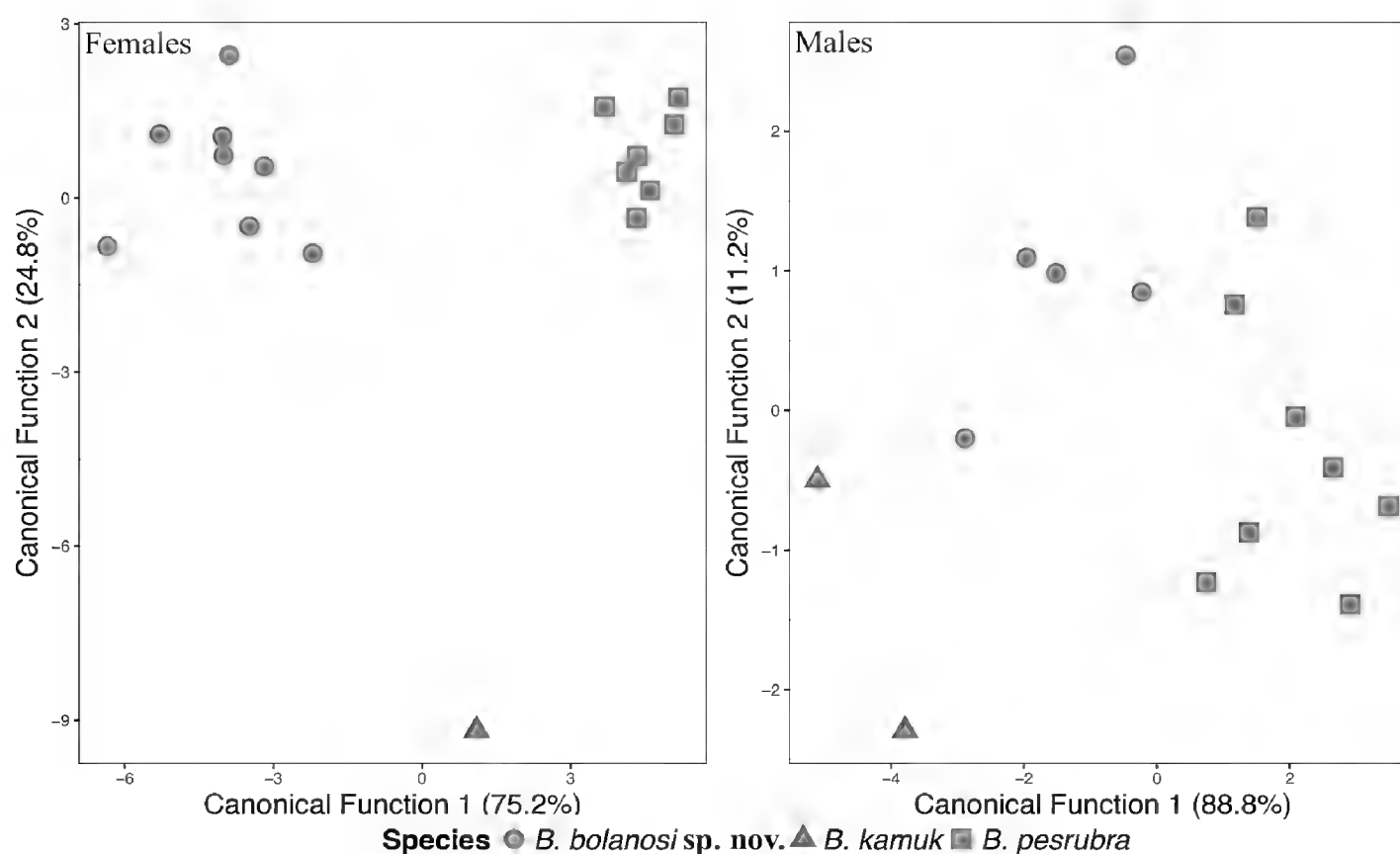
**Coloration in life.** The ground color of dorsal surfaces of the head, trunk, tail, hind limbs, and forelimbs is brownish black to brownish violet with numerous fine lighter patches of chromatophores scattered throughout the dorsal surface, especially concentrated on the head. The head and hindlimbs are lighter than the trunk. A pair of irregular dorsolateral stripes, which run from the tail base to the intercanthal area crossing the superior eyelids, are formed by yellowish-bronze blotches. The iris is bright dark bronze with a dark brownish-black reticulation. The upper surfaces of the arms are lighter than the trunk, pinkish brown, with orange blotches in the proximal portion of the humerus and on the ventrolateral surface of the ulna. The upper surface of the legs is similar in color to the trunk, uniform brownish black, except in the foot which is paler. The dorsal and dorsolateral surfaces of the tail are nearly uniform brownish black.

The ventrolateral surfaces of the body, tail, hindlimbs, and forelimbs are lighter than the dorsal surface. The gular surfaces are paler than the venter, consisting of lighter brown with a paler blotch on the anterior part, the mental gland. The ventral surface of the trunk and the tail are slightly lighter than the dorsal surface. The ventral surfaces of the arms and legs are lighter than the dorsal surfaces with irregular orange blotches. The palmar and plantar surfaces are light brown with black chromatophores.

**Coloration in ethanol.** After more than seven years in ethanol (70%), the overall coloration of the holotype has darkened throughout and contains a principal dark brown-blackish tone.

**Measurements (in mm), limb interval, and percentages of the holotype.** SL 49.05; TL 57.5; ShW 7.1; HeW 7.3; NeW 6.2; EW 3.2; SnL 3.4; JSL 8.2; LGFS 12.9; LNH 0.6; RNW 0.4; IND 3.1; NLP 1.1; ICD 3.9; HLL 13.1; FLL 12.6; TW 6.0; VGS 13.2; FSL 15.2; UHL 9.0; AGL 22.8; VL 4.9; HaW 4.8; HaL 5.4; LF2 2.3; LF3 3.0; WF3 1.0; FoW 5.7; FoL 5.5; LT2 1.9; LT3 2.7; WT3 0.9. Limb interval 1. Measurements in relative percentages: VGS/SL 26.9%; IND/HeW 42.5%; AGL/SL 46.5%; HeW/SL 14.9%; HeW/AGL 32.0%; SnL/HeW 46.6%; LNH/HeW 8.2%; LNH/SL 1.2%; RNW/HeW 5.5%; RNW/SL 0.8%; HLL/SL 26.7%; FLL/SL 25.7%; HaL/VGS 40.9%; FoL/VGS 41.7%; HaW/HeW 65.7%; FoW/HeW 78.1%; LT2/FoL 34.5%; LF2/HaL 42.6%; WT3/FoW 15.8%; WF3/HaW 20.8%.

**Noteworthy variation.** The female paratypes (UCR 22421 and UCR 24245) have more rounded snouts, and much less defined and protruding cirri or nasolabial protuberances, which are sexually dimorphic features. In coloration, this species is extremely polymorphic, some



**Fig. 3.** Linear discriminant analysis shows the morphological separation between the new species and the two species close to it.

individuals are almost uniform black, which is common in juveniles (UCR 22247, Fig. 6B). The paratopotype (UCR 22964, Fig. 6A) has the pair of dorsolateral stripes more vivid and continuous, the blotches in the upper eyelid are iridescent green; in addition, it has a band of pale orange from posterior head to tail, where it is suffused with the red of the tail. The presence of red on the tail is common; generally the red color in the proximal portion is only on the dorsal surface, but the tail becomes completely red in the distal portion. Several specimens showed a similar coloration morpho “mottled” (Fig. 6C), with ground color brownish black to reddish brown with numerous and irregular yellow to red blotches or spots; these specimens lack the dorsolateral stripes. The female UCR 24245 (Fig. 6D) has a striking coloration pattern formed by large yellow blotches about a brownish-black ground color; although less evident this specimen has the pair of dorsolateral stripes but the blotches are larger and suffused in the back.

**Measurements (in mm), limb intervals, and percentages of the paratypes.** SL 39.4–50.0; ShW 4.9–7.5; HeW 6.3–7.7; NeW 5.0–6.7; EW 1.8–3.2; SnL 2.4–3.4; JSL 6.0–8.2; LGFS 10.2–12.9; IND 1.7–3.1; NLP 0.7–1.1; ICD 2.9–3.9; HLL 9.9–13.1; FLL 8.9–17.6; TW 5.2–9.2; VGS 9.6–13.2; FSL 11.4–15.2; UHL 6.8–9.0; AGL 18.6–26.4; VL 3.5–5.1; HaW 3.0–4.8; HaL 3.4–5.4; LF2 1.3–2.3; LF3 1.8–3.0; WF3 0.7–1.1; FoW 3.4–5.7; FoL 3.8–5.5; LT2 1.5–2.1; LT3 1.7–2.9; WT3 0.7–1.2. Limb intervals 3–5. Measurements in relative percentages: VGS/SL 23.4–26.9%; IND/HeW 25.8–42.6%; AGL/SL 46.4–57.6%; HeW/SL 14.5–16.9%; HeW/AGL 25.2–35.7%; SnL/HeW 35.7–47.6%; HLL/SL 24.6–26.8%; FLL/SL 22.3–26.1%; HaL/VGS 32.7–40.5%; FoL/VGS 37.1–44.4%; HaW/HeW 48.0–66.3%; FoW/HeW 54.5–78.6%; LT2/HeW 24.1–31.9%; LT3/FoW 46.7–63.0%; LT2/FoL 34.9–45.8%; LF2/HaL 29.3–46.9%; WT3/FoW 15.5–24.1%; WF3/HaW 16.2–28.3%.

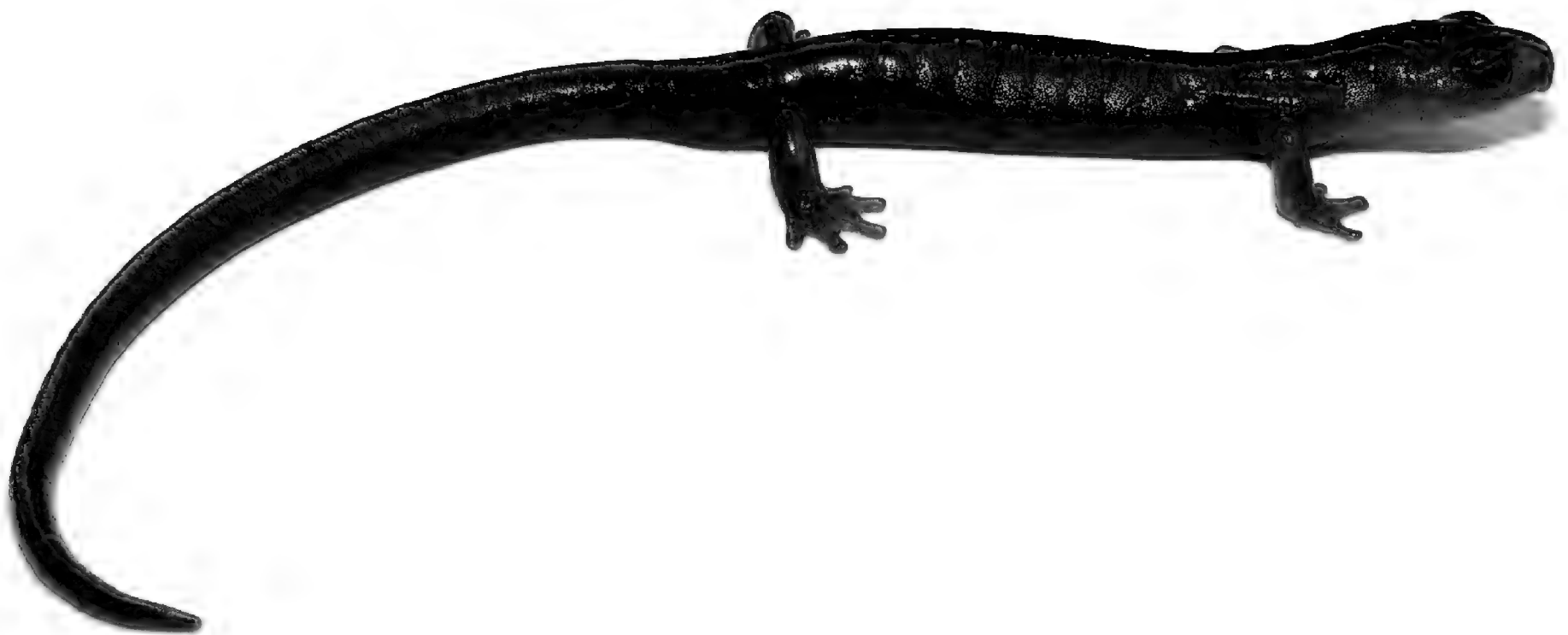
**Etymology.** The name “*bolanosi*” is a patronym honoring

the Costa Rican herpetologist Federico Bolaños, and is used as a noun in the genitive case. We name this species after our dear friend in recognition of his scientific contributions to the knowledge of the herpetology of Costa Rica, as curator of the Herpetology section at Museo de Zoología of Universidad de Costa Rica, and as the mentor of most herpetologists present in the country.

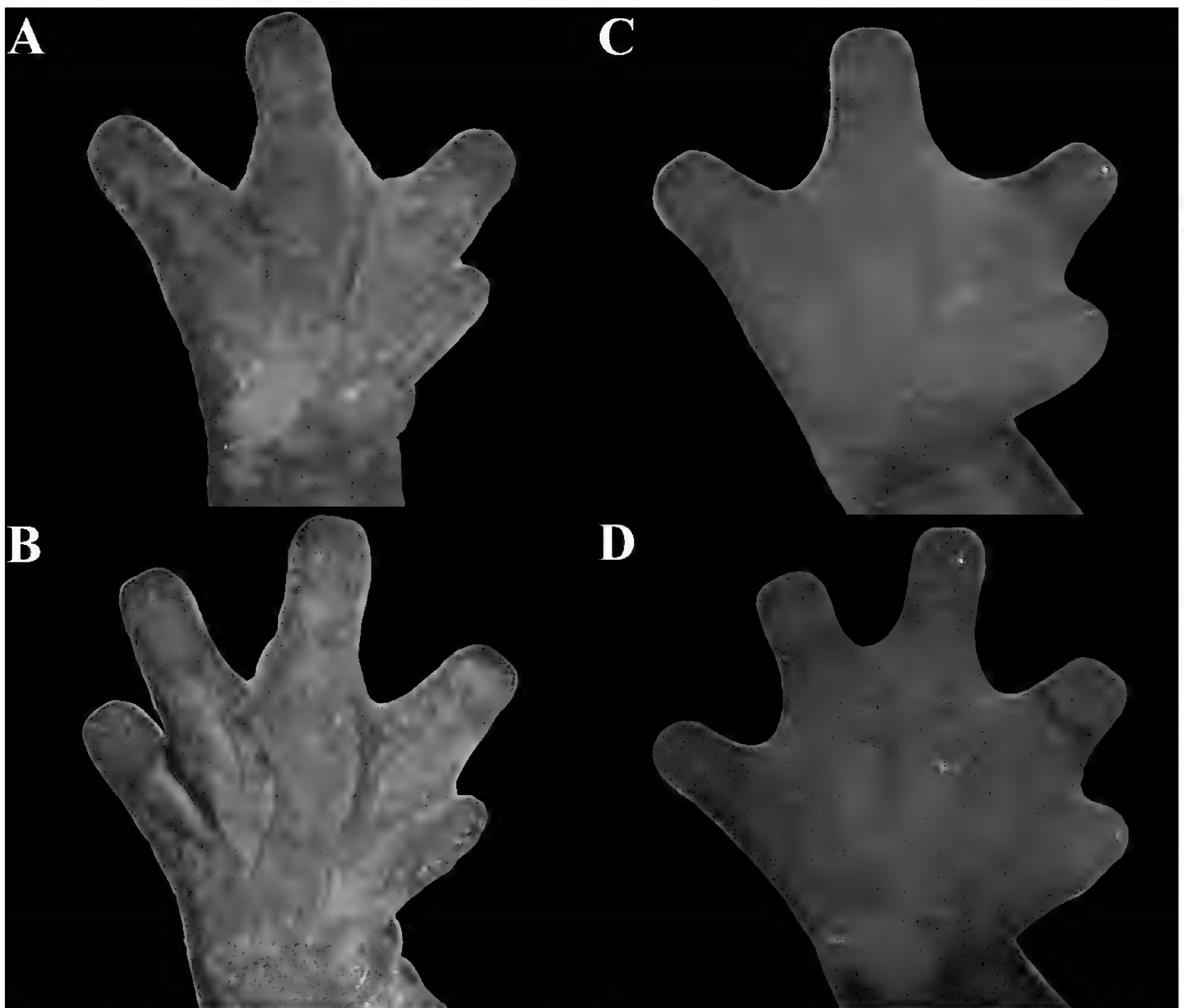
**Habitat and natural history observations.** The habitat of *Bolitoglossa bolanosi* in the subalpine rain páramo is characterized by having a very short dry season (one to two months), annual precipitation ranging from 1,000 to 2,000 mm, and annual temperatures between 3 and 6 °C. The páramo vegetation consists of extensive, deep moss mats, spongy soil, ferns, and small isolated trees with arboreal bromeliads. *Bolitoglossa bolanosi* was found within both moss and bromeliads. It also occurs in Montane rain forest which is dominated by *Quercus* covered with moss, with a great abundance of bryophytes and epiphytes. The type locality occurs in the Montane rain forest (Bolaños et al. 2005; Holdridge 1967), characterized by a very short dry season (one to two months), an annual precipitation range of 2,200 to 4,500 mm, and annual temperatures from 6 to 12 °C.

Very little is known about the natural history of *B. bolanosi*, but it is important to note that females guarding a clutch of eggs were found on Cerro Hakú (December 2015) and Cerro Dúrika (January 2016), both under moss on the floor. All specimens from Cerro Utyum were found within bromeliads at heights of >3 m over the soil, despite active searches in the moss of the páramo. Unlike in the peaks Dúrika, Arbolado, and Hakú, the specimens were mainly found in the moss at <2 m over soil, despite active searches in the bromeliads at >3 m above the ground (especially on Cerro Arbolado and Cerro Hakú). In the summit of Cerro Dúrika, *B. bolanosi* is very near (~4 km) to a site with *B. pesrubra*. In the summit of Cerro Utyum, it is to only ~7 km to a site with *B. kamuk*, and in this peak *B. bolanosi* is sympatric with an unnamed miniaturized salamander related to *B. pygmaea*. In addition, the type

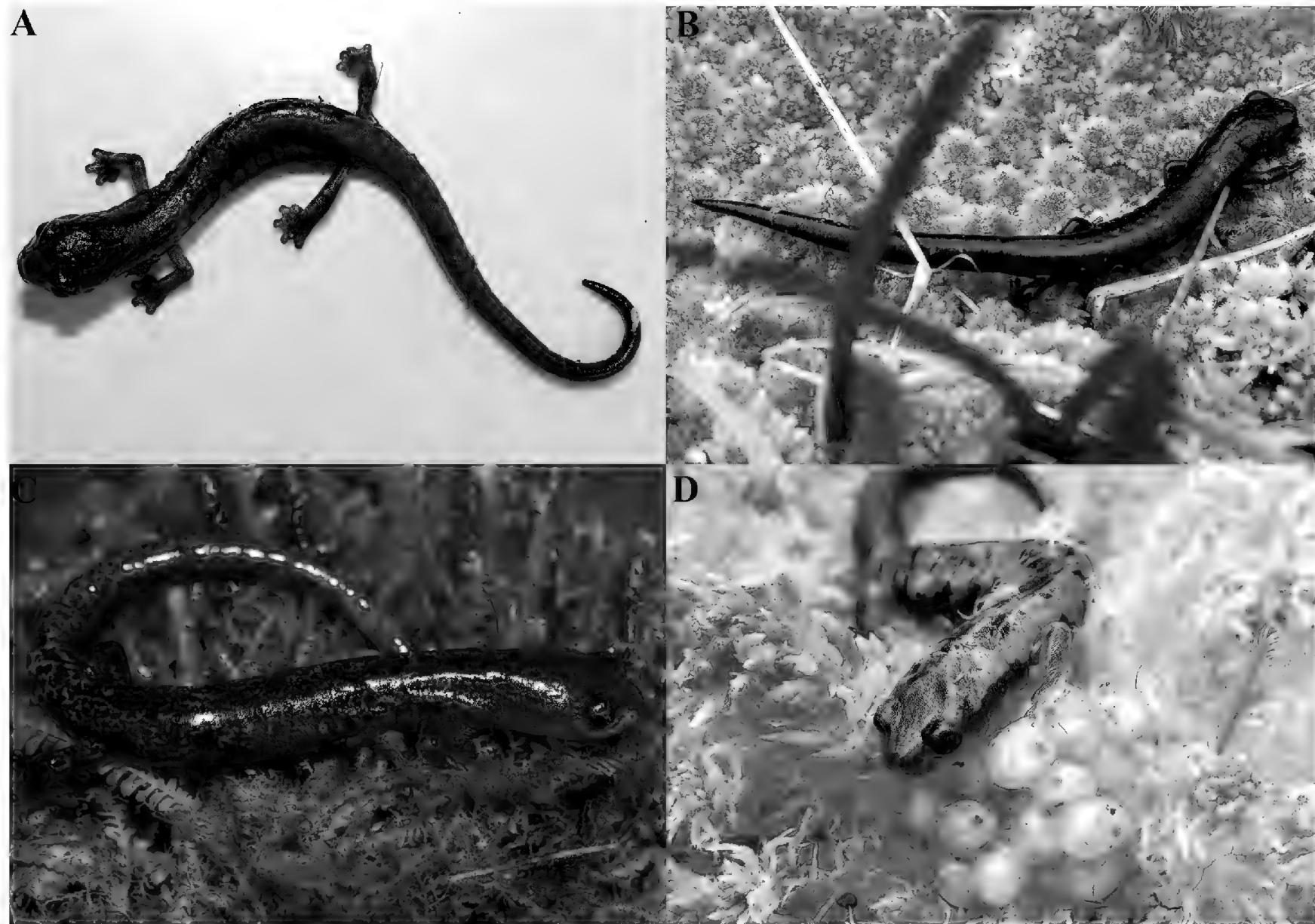




**Fig. 4.** Holotype of *Bolitoglossa bolanosi* **sp. nov.** (UCR 22965) in life on a white background. *Photograph by Erick Arias.*



**Fig. 5.** Dorsal views of the hand and foot of the holotypes of (A–B) *Bolitoglossa bolanosi* **sp. nov.** (UCR 22965) and (C–D) *B. pesrubra* in preservation. *Photograph by Erick Arias.*



**Fig. 6.** In-life photographs of variations within *Bolitoglossa bolanosi* sp. nov. (A) Paratopotype male subadult UCR 22966, (B) paratype juvenile UCR 24247, (C) paratype adult female UCR 22421, and (D) paratype adult female UCR 24245. Photographs A and C by Erick Arias, B and D by Omar Zúñiga.

locality of *B. splendida* is only ~4 km from the site with *B. bolanosi*.

**Distribution.** The known distribution area of *Bolitoglossa bolanosi* is very small, restricted throughout to ~15 km on the summits of the peaks Dúrika, Arbolado, Hakú, and Utyum on the Cordillera de Talamanca (Fig. 1). The altitudinal range of the new species is 2,550–3,240 m asl. All the populations of the new species were found in primary vegetation (páramo and forest) and all are within a protected area, La Amistad International Park.

**Conservation status.** The conservation status of this species is uncertain; however, its known distribution range is small (<20,000 km<sup>2</sup>) and all known populations are restricted to summits of peaks, sites that are highly vulnerable to forest fires and other effects of climate change. We suggest that it should be tentatively considered as Vulnerable (VU) following the IUCN (2017) category criteria.

## Discussion

Costa Rica hosts 56 species of salamanders, and it is the sixth most diverse country in the World in terms of total species richness and the most diverse relative to its total area (AmphibiaWeb 2023; Boza-Oviedo et al. 2012; Frost 2023). Several new species of salamanders have been described from ICA in this century (Arias and Kubicki

2018; Bolaños and Wake 2009; Boza-Oviedo et al. 2012; García-París et al. 2008; Hanken et al. 2005; Kubicki 2016; Kubicki and Arias 2016; Kubicki et al. 2022; Wake et al. 2007). Nevertheless, the taxonomic studies of salamanders in this region have been obscured due to a conservative morphology (Arias and Kubicki 2018; Boza-Oviedo et al. 2012; Kubicki et al. 2022). Recently, Kubicki et al. (2022) found low genetic distances among species of *Nototriton* from Costa Rica; however, they showed that two different species of *Nototriton* coexist (sympatry) in two sites, providing strong evidence of speciation. We also found relatively low (Table 1) genetic distances among the species of the *B. subpalmata* S.G., however, we found two sites separated by less than 7 km in a straight line from where two different species occur. In the first case, in the páramo of the Cerro Dúrika, samples of *B. bolanosi* (UCR 24245–7) were found only 4 km in a straight line from specimens of *B. pesrubra* (UCR 23049). The area separating these two sites consisted of homogeneous páramo, lacking any significant features that could be viewed as a barrier that would prevent the potential mixture of individuals or genes. However, the genetic distance among these organisms is 2.14% for 16S, providing evidence of genetic isolation. A second case was found in the páramo of the Cerro Utyum, where the *B. bolanosi* specimens (UCR 22421–7) were found only 7 km in a straight line from *B. kamuk* (UCR 23047). Similarly, these sites are separated by homogeneous páramo and we found genetic distances of 1.35–1.8% for

16S. We acknowledge the limitations of our conclusions, since our genetic analyses were based solely on the mitochondrial results. However, we think that all the evidence supports our hypothesis about the relationships within the *B. subpalmata* S.G.

*Bolitoglossa bolanosi* is the fourth species of salamander endemic to the páramo of ICA and the Montane rain forest surrounding it. The other three species also belong to the *B. subpalmata* S.G. Although there are relatively few species, the role of the páramos of ICA in the speciation of salamanders is interesting, especially since the páramos correspond only to 0.3% of the continental surface of Costa Rica (Kappelle and Horn 2016). The current isolated patches of páramos in ICA and its contraction-expansion dynamics in the past can explain (in part) the species formation in this habitat. In addition, it is noteworthy that the larger páramo in Costa Rica, the Cerro Chirripó, has not been sampled for salamanders. This páramo corresponds to two-thirds of all páramo in the country. There is a need for more studies in the páramos of ICA, especially due to the vulnerability of this ecosystem to climate change (Enquist 2002; Nogués-Bravo et al. 2007). In the past, *B. pesrubra* was relatively common (Bolaños and Wake 2009; Vial 1968). However, its populations have been greatly reduced (Boza-Oviedo et al. 2012; García-Paris et al. 2008), and we do not fully understand the cause of this reduction.

**Acknowledgements.**—We thank Laura Márquez-Valdelamar, Nelly López, and Andrea Jiménez-Marín for their laboratory assistance; Federico Bolaños for the use of specimens from the Museo de Zoología of the Universidad de Costa Rica; and Omar Zúñiga and Olmer Cordero who provided valuable assistance in the field during the expeditions. EA thanks the Posgrado en Ciencias Biológicas for supporting this study, the CONACyT for a student grant (CVU/Becario) 626946/330343, and the Programa de Innovación y Capital Humano para la Competitividad PINN-MICITT for a student grant (PED-0339-15-2). The fieldwork was partially supported by the National Geography Society (Grant number W-346-14). The laboratory work was partially funded by Dirección General de Asuntos del Personal Académico, UNAM, under grant PAPIIT-UNAM no. IN205521 to GPO. We acknowledge the Costa Rican Ministry of Environment and Energy (MINAE) for providing this expedition's corresponding scientific collecting permits (SINAC-SE-GAS-PI-R 007-2013 and 59-2015).

## Literature Cited

- AmphibiaWeb. 2023. AmphibiaWeb: Information on Amphibian Biology and Conservation. Berkeley, California, USA. Available: <http://amphibiaweb.org> [Accessed: 13 March 2023].
- Arias E, Kubicki B. 2018. A new moss salamander, genus *Nototriton* (Caudata: Plethodontidae), from the Cordillera de Talamanca, in the Costa Rica-Panama border región. *Zootaxa* 4369: 487–500.
- Bolanos F, Wake DB. 2009. Two new species of montane web-footed salamanders (Plethodontidae: *Bolitoglossa*) from the Costa Rica-Panama border region. *Zootaxa* 1981: 57–68.
- Bolaños R, Watson V, Tosi J. 2005. *Mapa Ecológico de Costa Rica (Zonas de Vida), Según el Sistema de Clasificación de Zonas de Vida del Mundo de L.R. Holdridge, Escala 1:750 000*. Centro Científico Tropical, San José, Costa Rica.
- Boza-Oviedo E, Rovito SM, Chaves G, García-Rodríguez A, Artavia LG, Bolaños F, Wake DB. 2012. Salamanders from the eastern Cordillera de Talamanca, Costa Rica, with descriptions of five new species (Plethodontidae: *Bolitoglossa*, *Nototriton*, and *Oedipina*) and natural history notes from recent expeditions. *Zootaxa* 3309: 36–61.
- Edgar RC. 2004. MUSCLE: multiple sequence alignment with high accuracy and high throughput. *Nucleic Acids Research* 32: 1,792–1,797.
- Enquist CAF. 2002. Predicted regional impacts of climate change on the geographical distribution and diversity of tropical forests in Costa Rica. *Journal of Biogeography* 29: 519–534.
- Frost DR. 2023. Amphibian Species of the World: an Online Reference. Version 6.0. American Museum of Natural History, New York, New York, USA. Available: <http://research.amnh.org/herpetology/amphibia/index.html> [Accessed: 13 March 2023].
- García-París M, Good DA, Parra-Olea G, Wake DB. 2000. Biodiversity of Costa Rican salamanders: implications of high levels of genetic differentiation and phylogeographic structure for species formation. *Proceedings of the National Academy of Sciences of the United States of America* 97: 1,640–1,647.
- García-París M, Parra-Olea G, Wake DB. 2008. Description of a new species of the *Bolitoglossa subpalmata* group (Caudata: Plethodontidae) from Costa Rica. *The Herpetological Journal* 18: 23–31.
- Hanken J, Wake DB, Savage JM. 2005. A solution to the large black salamander problem (genus *Bolitoglossa*) in Costa Rica and Panamá. *Copeia* 2005: 227–245.
- Holdridge LR. 1967. *Life Zone Ecology*. Revised edition. Tropical Science Center, San José, Costa Rica. 206 p.
- Kappelle M, Horn SP. 2016. The Páramo ecosystem of Costa Rica's highlands. Pp. 492–523 In: *Costa Rican Ecosystems*. Editor, Kappelle M. The University of Chicago Press, Chicago, Illinois, USA. 744 p.
- Kubicki B. 2016. A new species of salamander (Caudata: Plethodontidae: *Oedipina*) from the central Caribbean foothills of Costa Rica. *Mesoamerican Herpetology* 3: 819–840.
- Kubicki B, Arias E. 2016. A beautiful new yellow salamander, genus *Bolitoglossa* (Caudata: Plethodontidae), from the northeastern slopes of the Cordillera de Talamanca, Costa Rica. *Zootaxa* 4184: 329–346.
- Kubicki B, Reyes A, Arias E. 2022. Revised taxonomy and distributions of Costa Rican Moss Salamanders (Caudata: Plethodontidae: *Nototriton*), with descriptions of new taxa. *Zootaxa* 5194: 451–496.
- Lanfear R, Calcott B, Ho SY, Guindon S. 2012. Partition-Finder: combined selection of partitioning schemes and substitution models for phylogenetic analyses. *Molecular Biology and Evolution* 29: 1,695–1,701.
- Lanfear R, Frandsen PB, Wright AM, Senfeld T, Calcott



- B. 2017. PartitionFinder 2: new methods for selecting partitioned models of evolution for molecular and morphological phylogenetic analyses. *Molecular Biology and Evolution* 34: 772–773.
- Leonart J, Salat J, Torres GJ. 2000. Removing allometric effects of body size in morphological analysis. *Journal of Theoretical Biology* 205: 85–93.
- Miller MA, Pfeiffer W, Schwartz T. 2010. Creating the CIPRES Science Gateway for inference of large phylogenetic trees. Pp. 1–8 In: *Proceedings of the Gateway Computing Environments Workshop (GCE), 14 November 2010*. Institute of Electrical and Electronics Engineers, Piscataway, New Jersey, USA.
- Moritz C, Schneider CJ, Wake DB. 1992. Evolutionary relationships within the *Ensatina eschscholtzii* complex confirm the ring species interpretation. *Systematic Biology* 41: 273–291.
- Nogués-Bravo D, Araújo MB, Errea MP, Martínez-Rica JP. 2007. Exposure of global mountain systems to climate warming during the 21<sup>st</sup> century. *Global Environmental Change* 17: 420–428.
- Palumbi S, Martin A, Romano S, McMillan WO, Stice L, Grabowski G. 1991. *The Simple Fool's Guide to PCR, Version 2.0. Special Publication, Department of Zoology and Kewalo Marine Laboratory*. University of Hawaii, Honolulu, Hawaii, USA. 45 p.
- Parra-Olea G, García-París M, Wake DB. 2004. Molecular diversification of salamanders of the tropical American genus *Bolitoglossa* (Caudata: Plethodontidae) and its evolutionary and biogeographical implications. *Biological Journal of the Linnean Society* 81: 325–346.
- R Core Team. 2013. R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna, Austria. Version 3.3.3. Available: <https://www.R-project.org/>.
- Rambaut A, Suchard MA, Xie W, Drummond AJ. 2014. Tracer v1.6.1. Available: <http://beast.bio.ed.ac.uk/Tracer>.
- Ronquist F, Teslenko M, Van Der Mark P, Ayres DL, Darling A, Höhna S, Larget B, Liu L, Suchard M, Huelsenbeck JP. 2012. MrBayes 3.2: efficient Bayesian phylogenetic inference and model choice across a large model space. *Systematic Biology* 61: 539–542.
- Rovito SM, Parra-Olea G, Recuero E, Wake DB. 2015. Diversification and biogeographical history of Neotropical plethodontid salamanders. *Zoological Journal of the Linnean Society* 175: 167–188.
- Sambrook J, Russell DW. 2006. Purification of nucleic acids by extraction with phenol: chloroform. *Cold Spring Harbor Protocols* (2006): pdb-prot4455.
- Savage JM. 2002. *The Amphibians and Reptiles of Costa Rica: a Herpetofauna between Two Continents, between Two Seas*. The University of Chicago Press, Chicago, Illinois, USA. 934 p.
- Sukumaran JM, Holder MT. 2010a. SumTrees: Phylogenetic Tree Summarization. Version 4.4.0. Available: <https://github.com/jeetsukumaran/DendroPy>.
- Sukumaran JM, Holder MT. 2010b. DendroPy: A Python library for phylogenetic computing. *Bioinformatics* 26: 1,569–1,571.
- Tamura K, Stecher G, Peterson D, Filipski A, Kumar S. 2013. MEGA6: Molecular Evolutionary Genetics Analysis version 6.0. *Molecular Biology and Evolution* 30: 2,725–2,729.
- Vial JL. 1968. The ecology of the tropical salamander, *Bolitoglossa subpalmata*, in Costa Rica. *Revista de Biología Tropical* 15: 13–115.
- Wake DB. 1987. Adaptive radiation of salamanders in Middle American cloud forests. *Annals of the Missouri Botanical Garden* 74: 242–264.
- Wake DB, Savage JM, Hanken J. 2007. Montane salamanders from the Costa Rica-Panamá border region, with descriptions of two new species of *Bolitoglossa*. *Copeia* 2007: 556–565.
- Zwickl DJ. 2006. Genetic algorithm approaches for the phylogenetic analysis of large biological sequence datasets under the maximum likelihood criterion. Ph.D. Dissertation, The University of Texas, Austin, Texas, USA. 125 p.



**Erick Arias** is a Costa Rican herpetologist who earned his Bachelor's degree in Biology at Universidad de Costa Rica in 2013. Erick then joined Gabriela's Lab at Universidad Nacional Autónoma de México (UNAM) where he received a Doctorate in Systematics in 2019 studying the systematic, taxonomy, and biogeography of the neotropical frogs in the *Craugastor podiciferus* species group. In 2022, Erick joined the Universidad de Costa Rica as professor and researcher. Erick's current research focuses on the systematics, taxonomy, and biogeography of the amphibians and reptiles of Costa Rica, especially direct-developing frogs and salamanders.



**Gerardo Chaves** is a retired biologist, associated with the Zoology Museum of the University of Costa Rica. His undergraduate thesis focused on the arrival of Olive Ridley Sea Turtles, but most of his professional work has been oriented towards the ecology and taxonomy of the Costa Rican herpetofauna. His research activity is directed towards understanding the declines of amphibian populations in Mesoamerica and filling in information gaps in the Cordillera de Talamanca. From this research, he has published articles in several journals related to the ecology and taxonomy of Neotropical herpetofauna. Gerardo is currently the Chair of the IUCN Amphibian Specialist Group in Costa Rica.



**Gabriela Parra Olea** is a researcher at the Instituto de Biología, UNAM, Mexico, and curator of Mexico's national collection of amphibians and reptiles. Her research is focused on the molecular systematics and conservation of Mexican amphibians. Her laboratory is formed by students and postdocs all working on research projects in the systematics, taxonomy, conservation genetics, and impact of infectious diseases, specifically chytridiomycosis, on the conservation of amphibians.

**Appendix 1.** Institutional voucher numbers, locality information, and GenBank accession numbers for the specimens used in the molecular phylogenetic analyses. Museum collection acronyms follow Frost (2023) with the addition of EAP to refer to Erick Arias field numbers and CRARC to refer to the Costa Rica Amphibian Research Center private collection. NV= No voucher. CR = Costa Rica, HN = Honduras, MX = Mexico.

Species	Institutional voucher	Collection locality	Elevation (m)	Latitude	Longitude	16S	cyt b
<i>B. mexicana</i>	MVZ176838	Chiapas, MX	320	17.382	-91.793	GU725457	GU725470
<i>B. aurae</i>	UCR22842	Turrialba, Cartago, CR	1300	ND	ND	KX779527	KX779528
<i>B. sombra</i>	MVZ225875	Coto Brus, Puntarenas, CR	1760	8.954	-82.846	AY526136	AY526174
<i>B. compacta</i>	UCR20532	Talamanca, Limón, CR	2450	9.112	-82.962	JQ899163	JQ899193
<i>B. splendida</i>	UCR19835	Talamanca, Limón, CR	1826	9.357	-83.229	JQ899150	JQ899181
<i>B. bramei</i>	MVZ225893	Coto Brus, Puntarenas, CR	2200	8.935	-82.775	–	AF212066
<i>B. bramei</i>	UCR20483	Buenos Aires, Puntarenas, CR	2100	9.062	-82.984	JQ899159	JQ899189
<i>B. bramei</i>	UCR20484	Buenos Aires, Puntarenas, CR	2500	9.122	-82.964	JQ899160	JQ899190
<i>B. bramei</i>	UCR20851	Buenos Aires, Puntarenas, CR	2925	9.197	-83.056	JQ899142	JQ899172
<i>B. bramei</i>	UCR22719	Coto Brus, Puntarenas, CR	3160	9.031	-82.822	OR162559	OR147299
<i>B. bramei</i>	UCR22721	Coto Brus, Puntarenas, CR	3160	9.031	-82.822	OR162560	OR147300
<i>B. gomezi</i>	UCR20399	Buenos Aires, Puntarenas, CR	2100	9.139	-83.067	JQ899155	JQ899184
<i>B. gomezi</i>	UCR20413	Buenos Aires, Puntarenas, CR	2100	9.139	-83.067	–	JQ899185
<i>B. gomezi</i>	UCR20414	Buenos Aires, Puntarenas, CR	2100	9.139	-83.067	JQ899156	JQ899186
<i>B. gomezi</i>	UCR20415	Buenos Aires, Puntarenas, CR	2100	9.139	-83.067	JQ899157	JQ899187
<i>B. gomezi</i>	UCR20417	Buenos Aires, Puntarenas, CR	2100	9.139	-83.067	JQ899158	JQ899188
<i>B. gomezi</i>	UCR20843	Buenos Aires, Puntarenas, CR	2255	9.158	-83.065	JQ899140	JQ899170
<i>B. gomezi</i>	UCR20844	Buenos Aires, Puntarenas, CR	2100	9.139	-83.067	JQ899147	JQ899177
<i>B. gomezi</i>	UCR20845	Buenos Aires, Puntarenas, CR	2100	9.139	-83.067	JQ899148	JQ899178
<i>B. gomezi</i>	UCR20846	Buenos Aires, Puntarenas, CR	2100	9.139	-83.067	JQ899149	JQ899179
<i>B. gomezi</i>	UCR20847	Buenos Aires, Puntarenas, CR	2100	9.139	-83.067	–	JQ899180
<i>B. gomezi</i>	UCR20848	Buenos Aires, Puntarenas, CR	2255	9.158	-83.065	JQ899139	JQ899169
<i>B. gomezi</i>	UCR20849	Buenos Aires, Puntarenas, CR	2255	9.158	-83.065	JQ899141	JQ899171
<i>B. gomezi</i>	UCR20850	Buenos Aires, Puntarenas, CR	2100	9.139	-83.067	JQ899146	JQ899176
<i>B. gracilis</i>	MVZ229170	Paraíso, Cartago, CR	1680	9.692	-83.782	AY526121	AF212067
<i>B. gracilis</i>	MVZ229171	Paraíso, Cartago, CR	1680	9.692	-83.782	AY526122	AF212068
<i>B. gracilis</i>	UCR20541	Paraíso, Cartago, CR	1400	9.734	-83.764	OR162558	–
<i>B. tica</i>	UCR12065	Guarco, Cartago, CR	2440	9.686	-83.894	AY526137	AF212089

## A new species of *Bolitoglossa*

**Appendix 1 (continued).** Institutional voucher numbers, locality information, and GenBank accession numbers for the specimens used in the molecular phylogenetic analyses. Museum collection acronyms follow Frost (2023) with the addition of EAP to refer to Erick Arias field numbers and CRARC to refer to the Costa Rica Amphibian Research Center private collection. NV= No voucher. CR = Costa Rica, HN = Honduras, MX = Mexico.

Species	Institutional voucher	Collection locality	Elevation (m)	Latitude	Longitude	16S	cyt b
<i>B. tica</i>	UCR20514	Paraíso, Cartago, CR	2300	9.712	-83.858	JQ899162	JQ899192
<i>B. subpalmata</i>	MVZ190875	Barva, Heredia, CR	1850	10.133	-84.1	–	AF212093
<i>B. subpalmata</i>	MVZ194827	San Ramón, Alajuela, CR	1500	10.033	-84.483	–	AF212090
<i>B. subpalmata</i>	MVZ194828	San Ramón, Alajuela, CR	1500	10.033	-84.483	EU448107	AF212091
<i>B. subpalmata</i>	MVZ194889	Vazquez de Coronado, San José, CR	1700	9.998	-83.964	–	AF212095
<i>B. subpalmata</i>	MVZ229172	Monte Verde, Puntarenas, CR	1500	10.3	-84.7	AF416697	AF212094
<i>B. subpalmata</i>	NV-Braulio Carrillo	Heredia, CR	ND	ND	ND	–	AF212092
<i>B. subpalmata</i>	UCR20833	Alfaro Ruiz, Alajuela, CR	1600	10.177	-84.391	OR162562	–
<i>B. subpalmata</i>	UCR21783					OR162561	OR147301
<i>B. kamuk</i>	UCR20852	Talamanca, Limón, CR	3126	9.255	-83.059	JQ899143	JQ899173
<i>B. kamuk</i>	UCR20853	Talamanca, Limón, CR	3126	9.255	-83.059	JQ899144	JQ899174
<i>B. kamuk</i>	UCR20854	Talamanca, Limón, CR	3126	9.255	-83.059	JQ899145	JQ899175
<i>B. kamuk</i>	UCR23047	Talamanca, Limón, CR	2870	9.277	-83.135	OR162582	–
<i>B. bolanosi</i> <b>sp. nov.</b>	UCR22421	Talamanca, Limón, CR	2913	9.333	-83.18	OR162567	OR147303
<i>B. bolanosi</i> <b>sp. nov.</b>	UCR22422	Buenos Aires, Puntarenas, CR	2870	9.323	-83.187	OR162571	OR147307
<i>B. bolanosi</i> <b>sp. nov.</b>	UCR22423	Buenos Aires, Puntarenas, CR	2870	9.323	-83.187	OR162573	OR147309
<i>B. bolanosi</i> <b>sp. nov.</b>	UCR22424	Buenos Aires, Puntarenas, CR	2870	9.323	-83.187	OR162570	OR147306
<i>B. bolanosi</i> <b>sp. nov.</b>	UCR22425	Buenos Aires, Puntarenas, CR	2870	9.323	-83.187	OR162578	OR147312
<i>B. bolanosi</i> <b>sp. nov.</b>	UCR22426	Buenos Aires, Puntarenas, CR	2870	9.323	-83.187	OR162574	OR147310
<i>B. bolanosi</i> <b>sp. nov.</b>	UCR22427	Buenos Aires, Puntarenas, CR	2870	9.323	-83.187	OR162572	OR147308
<i>B. bolanosi</i> <b>sp. nov.</b>	UCR22741	Buenos Aires, Puntarenas, CR	2660	9.322	-83.203	OR162580	OR147313
<i>B. bolanosi</i> <b>sp. nov.</b>	UCR22742	Buenos Aires, Puntarenas, CR	2660	9.322	-83.203	OR162576	OR147311
<i>B. bolanosi</i> <b>sp. nov.</b>	UCR22743	Buenos Aires, Puntarenas, CR	2660	9.322	-83.203	OR162579	–
<i>B. bolanosi</i> <b>sp. nov.</b>	UCR22744	Buenos Aires, Puntarenas, CR	2660	9.322	-83.203	OR162577	–
<i>B. bolanosi</i> <b>sp. nov.</b>	UCR22745	Buenos Aires, Puntarenas, CR	2660	9.322	-83.203	OR162575	–
<i>B. bolanosi</i> <b>sp. nov.</b>	UCR22746	Buenos Aires, Puntarenas, CR	2660	9.322	-83.203	OR162581	–
<i>B. bolanosi</i> <b>sp. nov.</b>	UCR22965	Buenos Aires, Puntarenas, CR	2600	9.32	-83.216	OR162566	–



**Appendix 1 (continued).** Institutional voucher numbers, locality information, and GenBank accession numbers for the specimens used in the molecular phylogenetic analyses. Museum collection acronyms follow Frost (2023) with the addition of EAP to refer to Erick Arias field numbers and CRARC to refer to the Costa Rica Amphibian Research Center private collection. NV= No voucher. CR = Costa Rica, HN = Honduras, MX = Mexico.

Species	Institutional voucher	Collection locality	Elevation (m)	Latitude	Longitude	16S	cyt b
<i>B. bolanosi</i> <b>sp. nov.</b>	UCR24245	Buenos Aires, Puntarenas, CR	3240	9.374	-83.303	OR162568	OR147304
<i>B. bolanosi</i> <b>sp. nov.</b>	UCR24246	Buenos Aires, Puntarenas, CR	3240	9.374	-83.303	OR162569	OR147305
<i>B. pesrubra</i>	CRARC0190	Dota, San José, CR	2750	9.652	-83.849	OR162585	OR147314
<i>B. pesrubra</i>	CRARC0192	Dota, San José, CR	2750	9.652	-83.849	OR162586	OR147315
<i>B. pesrubra</i>	DBW5117	ND	ND	ND	ND	–	AF212081
<i>B. pesrubra</i>	DBW5118	ND	ND	ND	ND	–	AF212082
<i>B. pesrubra</i>	EAP0771	Buenos Aires, Puntarenas, CR	2850	9.345	-83.39	OR162563	OR147302
<i>B. pesrubra</i>	MVZ190923	Dota, San José, CR	2760	9.623	-83.832	EU448104	AF212074
<i>B. pesrubra</i>	MVZ190928	Guarco, Cartago, CR	2760	9.626	-83.832	–	AF212072
<i>B. pesrubra</i>	MVZ195598	Guarco, Cartago, CR	2930	9.614	-83.804	–	AF212076
<i>B. pesrubra</i>	MVZ210360	Guarco, Cartago, CR	3230	9.567	-83.733	EU448105	–
<i>B. pesrubra</i>	MVZ225881	Guarco, Cartago, CR	2980	9.617	-83.833	–	AF212075
<i>B. pesrubra</i>	MVZ231322	Guarco, Cartago, CR	2760	9.626	-83.832	–	AF212074
<i>B. pesrubra</i>	NV-Asunción	Guarco, Cartago, CR	3230	9.567	-83.733	–	AF212080
<i>B. pesrubra</i>	NV-Cerro de la Muerte	Guarco, Cartago, CR	2980	9.617	-83.833	–	AF212077
<i>B. pesrubra</i>	NV-Cerro de la Muerte					OR162588	OR147316
<i>B. pesrubra</i>	NV-Empalme	Guarco, Cartago, CR	2700	9.626	-83.836	–	AF212078
<i>B. pesrubra</i>	NV-Georgina	Paraíso, Cartago, CR	3100	9.567	-83.717	–	AF212083
<i>B. pesrubra</i>	NV-Mills	Paraíso, Cartago, CR	3000	9.552	-83.717	–	AF212084
<i>B. pesrubra</i>	NV-Sakira	Pérez Zeledón, San José, CR	3400	9.592	-83.761	–	AF212079
<i>B. pesrubra</i>	NV-Salsipuedes	Guarco, Cartago, CR	2530	9.65	-83.85	–	AF212070
<i>B. pesrubra</i>	UCR12068	Guarco, Cartago, CR	2680	9.652	-83.849	AY526132	AF212069
<i>B. pesrubra</i>	UCR16471	Pérez Zeledón, San José, CR	3300	9.587	-83.765	OR162583	–
<i>B. pesrubra</i>	UCR20251	Paraíso, Cartago, CR	2760	9.556	-83.686	OR162587	–
<i>B. pesrubra</i>	UCR20859	Guarco, Cartago, CR	2800	9.669	-83.852	OR162584	–
<i>B. pesrubra</i>	UCR23048	Talamanca, Limón, CR	3050	9.395	-83.335	OR162564	–
<i>B. pesrubra</i>	UCR23049	Talamanca, Limón, CR	3000	9.368	-83.347	OR162565	–

**Appendix 2.** Specimens examined in the morphological analysis. All voucher numbers below are ‘UCR’ numbers, and the specimens were housed at the Museo de Zoología at the Universidad de Costa Rica.

*Bolitoglossa bolanosi* **sp. nov.**

COSTA RICA: Limón, Talamanca, Cerro Utyum: (22421♀); Puntarenas, Buenos Aires, Cerro Arbolado: (22965♂); Puntarenas, Buenos Aires, Cerro Hakú: (24245♀, 24246♂); Puntarenas, Buenos Aires, Cerro Hakú: (22741–4♀, 22745♂); Puntarenas, Buenos Aires, Cerro Utyum: (22422♂, 22423♀, 22424♂, 22425♀).

*Bolitoglossa kamuk*

COSTA RICA: Limón, Talamanca, Cerro Diká: (23047♀); Limón, Talamanca, Cerro Kamuk: (20852–3♂).

*Bolitoglossa pesrubra*

COSTA RICA: Cartago, El Guarco, Cerro de la Muerte: (23912♂, 22436♀); Cartago, Paraíso, Cerro de la Muerte: (13810♂, 19034♂, 19125♀, 19099♀, 23634♂); San José, Dota, Cerro de la Muerte: (12067♂, 20793♀, 20797–9♀); San José. Pérez Zeledón, Cuericí: (11712♂, 11757♂, 12109♂).



urn:lsid:zoobank.org:pub:FB17AF57-AAE5-4668-8D22-1722DAEF4AA5

# Two new species of gymnophthalmid lizards of the genus *Petracola* (Squamata: Cercosaurinae) from the Andes of northeastern Peru, and their phylogenetic relationships

<sup>1,2,3,\*</sup>Luis Mamani, <sup>4,5</sup>Víctor J. Vargas, <sup>2,3</sup>Juan C. Chaparro, and <sup>6</sup>Alessandro Catenazzi

<sup>1</sup>Programa de Doctorado en Sistemática y Biodiversidad, Facultad de Ciencias Naturales y Oceanográficas, Universidad de Concepción (UdeC), Concepción, CHILE <sup>2</sup>Museo de Historia Natural de la Universidad Nacional de San Antonio Abad del Cusco (MHNC), Plaza de Armas s/n (Paraninfo Universitario), Cusco, PERU <sup>3</sup>Museo de Biodiversidad del Perú (MUBI), Cusco, PERU <sup>4</sup>Asociación Pro Fauna Silvestre Ayacucho, Huamanga, Ayacucho, PERU <sup>5</sup>Servicio Nacional Forestal y de Fauna Silvestre (SERFOR), Lima, PERU <sup>6</sup>Department of Biological Sciences, Florida International University (FIU), Miami, Florida 33199, USA

**Abstract.**—The small and semi-fossorial lizards of the genus *Petracola* are distributed in the Andes from central to northern Peru, on both sides of the dry valley of the Marañón River. Very little is known about the taxonomy of *Petracola*, but it is presumed that this genus harbors a higher number of species than is currently known. Here, we used a Maximum Likelihood (ML) molecular phylogenetic analysis using concatenated fragments of four mitochondrial genes (12S, 16S, cyt-*b*, and ND4) and one nuclear gene (*c-mos*), and the revision of museum specimens, to determine the species diversity of populations of *Petracola* on both sides of the Marañón River. Our results show that *Petracola* is a monophyletic genus composed of three independent lineages. The first lineage includes two undescribed species from the right side of the Marañón River, which we describe herein. The second lineage corresponds to *P. ventrimaculatus*, and the third lineage includes *P. waka* which contains undescribed species. Among the two new species from the right side of the Marañón River, *P. amazonensis* can be identified by having only the first superciliary expanded to the dorsal surface, two pairs of genials in contact, absence of a loreal scale, venter orange with black spots forming a transverse band, absence of precloacal pores, and a maximum SVL of 43.0 mm in females; whereas *P. shurugojaicapi* can be identified by having two genials in contact, absence of a loreal scale, two discontinuous superciliaries, black venter, dorsum dark brown or black with some cream spots, and an absence of precloacal pores. The two new species increase the diversity of this genus to seven species, four of which inhabit the right side of the dry valley of the Marañón River. However, like other genera of gymnophthalmid Andean lizards, the diversity of *Petracola* is still underestimated.

**Keywords.** Andean lizard, Cercosaurini, dry valley, endemic species, northern Andes, Marañón River, semi-fossoriality

**Citation:** Mamani L, Vargas VJ, Chaparro JC, Catenazzi A. 2023. Two new species of gymnophthalmid lizards of the genus *Petracola* (Squamata: Cercosaurinae) from the Andes of northeastern Peru, and their phylogenetic relationships. *Amphibian & Reptile Conservation* 17(1 & 2) [Taxonomic Section]: 161–173 (e328).

**Copyright:** © 2023 Mamani et al. This is an open access article distributed under the terms of the Creative Commons Attribution License [Attribution 4.0 International (CC BY 4.0): <https://creativecommons.org/licenses/by/4.0/>], which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited. The official and authorized publication credit sources, which will be duly enforced, are as follows: official journal title *Amphibian & Reptile Conservation*; official journal website: [amphibian-reptile-conservation.org](http://amphibian-reptile-conservation.org).

**Accepted:** 4 October 2023; **Published:** 30 December 2023

## Introduction

The genus *Petracola* Doan and Castoe, 2005, is a poorly studied Andean lineage of small and semi-fossorial lizards distributed in the central and northern Andes of Peru, on both margins of the dry valley of the Marañón River (DVMR) (Doan and Castoe 2005; Kizirian et al. 2008; Köhler and Lehr 2004; Uzzell 1970). The species of *Petracola* inhabit ecosystems of montane cloud forests, inter-Andean valleys, and wet *puna* at elevations from 1,889 to 3,600 m asl.

The systematics and taxonomy of *Petracola* are poorly developed, and geographic information gaps prevent an appreciation of the full diversity and distribution of the genus. The type species of *Petracola*, *P. ventrimaculatus* (Boulenger, 1900), was initially assigned to *Proctoporus* by Boulenger (1900). Previously, based on morphological characters such as the presence of smooth dorsal scales, three postparietal scales, short limbs, and the presence of entire palpebral disc, Uzzell (1970) assigned *P. ventrimaculatus* to the *Proctoporus pachyurus* group. Further analyses based on molecular data and a taxonomic

**Correspondence.** [luismamani@gmail.com](mailto:luismamani@gmail.com)



review led to the creation of the genus *Petracola* (Castoe et al. 2004; Doan and Castoe 2005), which has been supported by recent studies (Goicoechea et al. 2012; Mamani et al. 2020, 2022; Moravec et al. 2018; Torres-Carvajal et al. 2016). Species of *Petracola* are phylogenetically related to Andean speciose lineages containing *Cercosaura*, *Potamites*, and *Proctoporus*, and minor lineages such as “*Cercosaura manicata boliviana*,” *Dendrosauridion*, *Selvasaura*, and *Wilsonosaura* (Mamani et al. 2020, 2022; Moravec et al. 2018; Rojas-Runjaic et al. 2021). Despite the increasing knowledge about high-Andean gymnophthalmids accumulated over the past decade, the diversity of gymnophthalmid species continues to be underestimated.

Currently, the genus contains five species: *Petracola angustisoma* Echevarría and Venegas, 2015; *P. labioocularis* (Köhler and Lehr, 2004); *P. pajatensis* Rodríguez and Mamani, 2020; *P. ventrimaculatus*, and *P. waka*, Kizirian, Bayefsky-Anand, Eriksson, Le and Donnelly 2008. Although Kizirian et al. (2008) hypothesized that *P. ventrimaculatus* and *P. waka* represent complexes of species, only two more species have been described since 2015 (Echevarría and Venegas 2015; Rodríguez and Mamani 2020). Moreover, this genus has a peculiar distribution on both sides of the DVMR, in which *Petracola angustisoma* and *P. pajatensis* are distributed on the right side (Echevarría and Venegas 2015; Köhler and Lehr 2004; Rodríguez and Mamani 2020), *P. waka* is distributed on the left side, and *P. ventrimaculatus* is distributed on both sides of the Marañón River (Kizirian et al. 2008).

Vicariant topographic features such as the DVMR introduce genetic barriers between populations on the two sides of the valley, promoting the diversification of lineages (Futuyma and Kirkpatrick 2017). The ornithological literature supports the hypothesis that the arid valley of the DVMR interrupts gene flow between populations and promotes allopatric speciation (Hazzi et al. 2018; Weir 2009; Winger and Bates 2015), but this hypothesis has not been tested in other biological groups, and especially in philopatric organisms such as gymnophthalmid lizards (Doan et al. 2021). Here, based on an analysis of morphological data and molecular phylogenetic relationships of four mitochondrial genes (12S, 16S, *cyt-b*, and ND4) and one nuclear gene (*c-mos*) from specimens collected on both sides of the DVMR, we evaluated the hypothesis proposed by Kizirian et al. (2008) that *Petracola ventrimaculatus* and *P. waka* are species complexes, and we describe two new species from those complexes.

## Material and Methods

### Data Collection and Morphology

Specimens of the new species were collected in Department Amazonas, Peru, and are deposited in the Colección Científica Pro Fauna Ayacucho (PFAUNA) and the Museo de Biodiversidad del Perú (MUBI). Specimens were collected by hand, euthanized, fixed in 10% formalin, and

stored in 70% ethanol. Tissue samples were stored in 2 ml cryogenic tubes filled with 96% ethanol. The terminology for diagnostics and format description follows Uzzell (1970), Kizirian (1996), Mamani et al. (2022), and Mamani and Rodríguez (2022). Measurements were taken with calipers to the nearest 0.1 mm. Abbreviations for measurements are as follows: SVL (snout-vent length), TL (tail length), LAL (length between arm and leg), LSA (length from the tip of snout to anterior margin of the insertion of the arm), HL (head length, from the tip of snout to posterior margin of tympanum), HW (head width, maximum width of head), HH (head height, maximum height of head), FR (frontal length), and FN (frontonasal length). Morphological data of *Petracola* species were taken from the literature (Echevarría and Venegas 2015; Kizirian et al. 2008; Köhler and Lehr 2004; Rodríguez and Mamani 2020) and the examination of voucher specimens deposited at the Museo de Historia Natural de la Universidad Nacional de San Marcos (MUSM), Lima, Peru; Museo de Biodiversidad del Perú (MUBI), Cusco, Peru; and Colección Científica Pro Fauna Silvestre (PFAUNA), Ayacucho, Peru. The specimens examined are listed in Appendix I.

### DNA Extraction, Amplification, Sequencing, and Phylogenetic Reconstruction

We extracted DNA from the tissue samples of seven voucher specimens of *Petracola* (Table 1) from both sides of the DVMR. We used standard protocols (Mamani et al. 2020) to amplify fragments of the small subunit rRNA (12S), large subunit rRNA (16S), dehydrogenase subunit 4 (ND4), cytochrome b (*cyt-b*), and oocyte maturation factor gene (*c-mos*). The new DNA sequences are available in GenBank (Appendix 1; <https://www.ncbi.nlm.nih.gov/genbank/>). We obtained additional sequences of congeneric species and representative species of different gymnophthalmid genera and outgroups (following Moravec et al. 2018) from GenBank. We excluded *Petracola ventrimaculatus* (AY507894) from our data set of the gene ND4, because the sample was nested within *Cercosaura* genus in a previous exploratory analysis, suggesting a possible labeling error or contamination. The final data set contained 137 operational taxonomic units (OTU) and 2,384 bp of concatenated fragments (458 bp for 12S, 561 bp for 16S, 345 bp for *cyt-b*, 639 bp for ND4, and 381 bp for *c-mos*) (Table S1).

The genetic sequences were aligned using MUSCLE software (Edgar 2004) implemented in MEGA-X (Kumar et al. 2018). We inferred the phylogenetic relationships using a Maximum Likelihood (ML) approach in IQTREE Web server (Trifinopoulos et al. 2016). The evolution models were estimated in ModelFinder (Kalyaanamoorthy et al. 2017) and were TIM2+F+I+G4 for 12S, GTR+F+R4 for 16S, TIM2e+I+G4 for *cytb*, GTR+F+R5 for ND4, and TPM3+F+G4 for *c-mos*. Branch supports were estimated for 10,000 replicates using ultrafast Bootstrap (Hoang et al. 2018). Following Moravec et al. (2018), we used *Alopoglossus atriventris*, *Bachia bresslaui*, *B. dorbignyi*, *B. flavescens*, *Ecpleopus gaudichaudii*, *Gymnophthalmus*

**Table 1.** Voucher museum specimens of *Petracola* lizards, mentioning their collection locations and GenBank codes sequences used in this study. All localities are from Peru.

Species/voucher	Locality	12S	16S	ND4	cytb	c-mos
<i>P. amazonensis</i> MUBI 11473	Chiliquin, Chachapoyas, Amazonas	OR231541	OR231652	OR208583	OR198057	OR211561
<i>P. shurugojaicapi</i> MUBI 17727	La Jalca, Chachapoyas, Amazonas	OR231542	OR231653	-	OR198058	OR211562
<i>P. shurugojaicapi</i> PFAUNA 430	La Jalca, Chachapoyas, Amazonas	OR231543	OR231654	-	OR198059	OR211563
<i>P. waka</i> MUBI 2603	Baños del Inca, Cajamarca, Cajamarca	OR231544	OR231655	OR208584	OR198060	OR211564
<i>P. waka</i> MUBI 2605	Baños del Inca, Cajamarca, Cajamarca	OR231545	OR231656	OR208585	OR198061	OR211565
<i>P. waka</i> MUBI 2609	Type locality, Cajabamba, Cajamarca	OR231546	OR231657	OR208586	OR198062	-
<i>P. waka</i> MUBI 2611	Type locality, Cajabamba, Cajamarca	OR231547	OR231658	OR208587	OR198063	OR211566

*leucomystax*, *Rhachisaurus brachylepis*, *Riolama inopinata*, and *R. leucosticta* as outgroup taxa.

We estimated uncorrected *p*-distances between species of *Petracola* for the 16S gene using MEGA-X (Kumar et al. 2018). Genetic distances for 16S larger than 3% separate most species of gymnophthalmid lizards (Torres-Carvajal et al. 2015).

The electronic version of this article in Portable Document Format (PDF) will represent a published work according to the International Commission on Zoological Nomenclature (ICZ), and hence the new name contained in the electronic version is effectively published under the Code from the electronic edition alone. This published work and the nomenclatural acts it contains have been registered in ZooBank, the online registration system for the ICZN. The ZooBank LSIDs (Life Science Identifiers) can be resolved, and the associated information viewed through any standard web browser by appending the LSID to the prefix <http://zoobank.org/>. The LSID for this publication is: urn:lsid:zoobank.org:pub:FB17AF57-AAE5-4668-8D22-1722DAEF4AA5.

Results

Phylogenetic Relationships and Generic Assignment

The ML tree recovered the monophyly of the ingroup Cercosaurinae (ultrafast bootstrap, UB = 100; Figs. 1 and S1). Our topology recovered the monophyly of all genera with high support, except *Proctoporus* (UB = 52). The monophyly of *Oreosaurus* was not supported, because *O. serranus* was recovered as a different lineage of *Oreosaurus*, with *Cercosaura*, “*Cercosaura manicata boliviana*,” *Dendrosauridion*, *Petracola*, *Potamites*, *Proctoporus*, and *Wilsonosaura* as its closest relatives.

The genus *Petracola* was recovered with high support (UB = 100) as sister lineage of *Cercosaura*, “*Cercosaura*

*manicata boliviana*,” *Dendrosauridion*, *Potamites*, *Proctoporus*, *Selvasaura*, and *Wilsonosaura* (Fig. 1). The specimens of *Petracola* from the left side of the DVMR were monophyletic, and include *P. ventrimaculatus* and *P. waka*, but the node support was low (UB = 83). Three specimens from the right side of the DVMR, including the two new species (*P. amazonensis* and *P. shurugojaicapi*), were recovered as sister lineages with high support (UB = 100) and have high uncorrected *p*-distances for the 16S gene ranging from 3.7% to 8.0% (Table 2), suggesting they might be distinct from the currently recognized taxa. Additionally, the distance between specimens of *P. waka* from the type locality (MUBI 2609, 2611) and those from Baños del Inca and Abra Gelic is 6.3–6.6%, which suggests a hidden cryptic diversity (Table 2).

Finally, our phylogeny and morphological traits such as presence of imbricate and scale-like papillae on the tongue, scales of the head without striations or rugosities, smooth dorsal scales, and absence of prefrontal scales (Doan and Castoe 2005), support the assignment to the genus *Petracola*.

Taxonomy

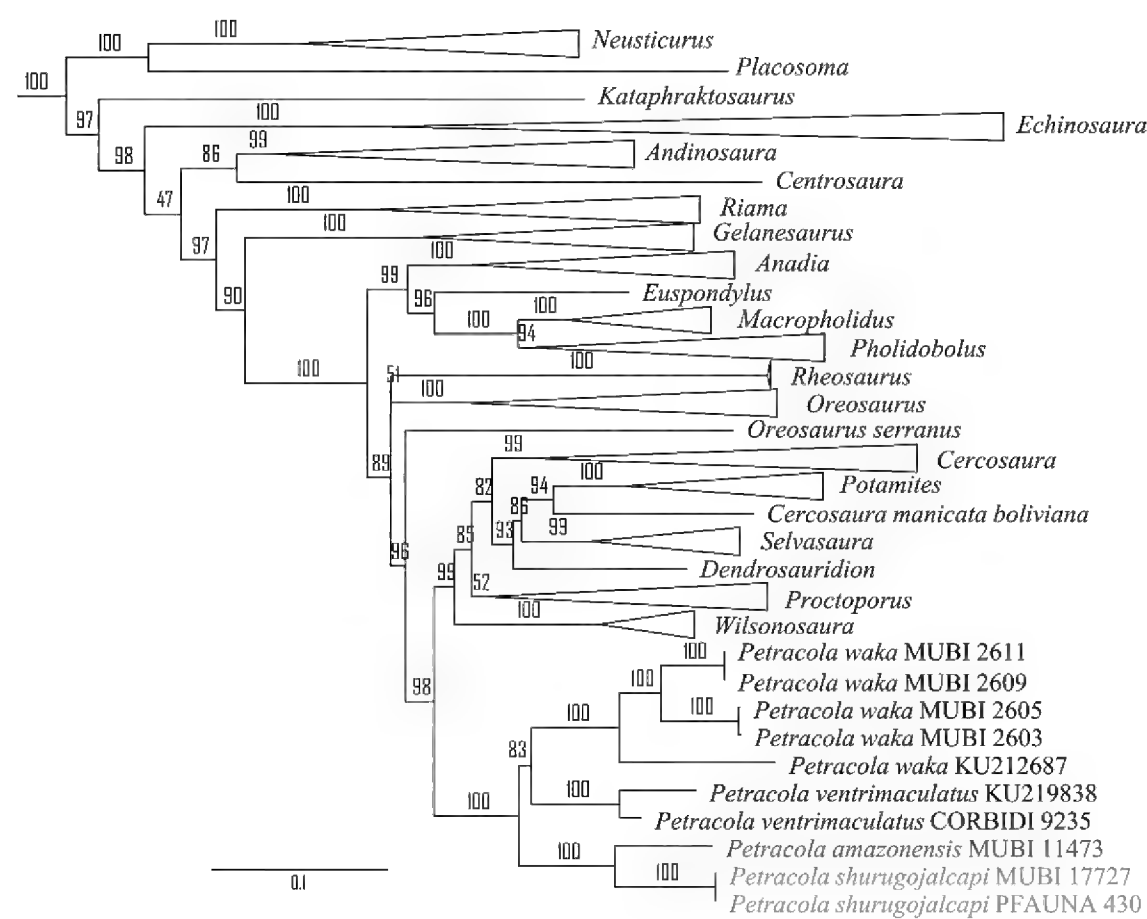
*Petracola amazonensis* sp. nov.

urn:lsid:zoobank.org:act:89A5D519-171D-4906-B82B-6C60CB8F9854

**Holotype.** MUBI 11485, adult female (Figs. 2–4) from Upa, bridge path to Yurumarca, District of Chiliquin, Province of Chachapoyas, Department of Amazonas, Peru (6°0’9.19” S; 77°49’21.08” W; ca. 3,020 m asl), collected by Juan C. Chaparro on 23 May 2012.

**Paratypes.** Two specimens: A subadult male (MUBI 11473) and a subadult female (MUBI 11474) from near the type locality (5°59’40.27” S; 77°48’36.26” W; 3,250 m asl), collected by Juan C. Chaparro and Alexander Pari on 22 May 2012.

Two new species of *Petracola* from Peru



**Fig. 1.** Phylogenetic relationships of Cercosaurini (log likelihood = -54268.289, ultrafast bootstrap = 10,000) constructed from the data set of 2,384 nucleotides for mitochondrial genes (12S, 16S, cyt-b, and ND4) and a nuclear gene (c-mos), showing species of *Petracola* and the two new species *Petracola amazonensis* and *P. shurugoalcapi*. The numbers on the branches are ultrafast bootstraps values.

**Table 2.** Pairwise uncorrected *p*-distances for 16S rRNA between *Petracola* species. The asterisk (\*) indicates type locality.

	1	2	3	4	5	6	7	8	9	10
(1) <i>P. ventrimaculatus</i> CORBIDI 9235	-									
(2) <i>P. ventrimaculatus</i> KU 219838	0.024	-								
(3) <i>P. waka</i> KU 212687	0.063	0.071	-							
(4) <i>P. waka</i> MUBI 2603	0.073	0.091	0.063	-						
(5) <i>P. waka</i> MUBI 2605	0.073	0.091	0.063	0.000	-					
(6) <i>P. waka</i> MUBI 2609*	0.069	0.082	0.066	0.031	0.031	-				
(7) <i>P. waka</i> MUBI 2611*	0.069	0.082	0.066	0.031	0.031	0.000	-			
(8) <i>P. shurugoalcapi</i> MUBI 17727	0.058	0.074	0.080	0.079	0.079	0.079	0.079	-		
(9) <i>P. shurugoalcapi</i> PFAUNA 430	0.058	0.074	0.080	0.079	0.079	0.079	0.079	0.000	-	
(10) <i>P. amazonensis</i> MUBI 11473	0.057	0.072	0.085	0.078	0.078	0.072	0.072	0.037	0.037	-

**Etymology.** The specific epithet, *amazonensis*, is an adjective in reference to the type locality in the Department of Amazonas, northern Peru.

**Diagnosis:** *Petracola amazonensis* is diagnosed based on the following combination of characters: (1) frontonasal longer than frontal; (2) nasoloreal suture absent; (3) two supraoculars; (4) one superciliary scale expanded on dorsal surface of head; (5) two postoculars; (6) palpebral disc transparent, entire or divided vertically in two; (7) four supralabials anterior to the posteroventral angle of the subocular; (8) 3–4 anterior infralabials; (9) four

genials in contact; (10) three rows of prelinguals; (11) dorsal body scales rectangular, smooth, juxtaposed; (12) 25–28 scales around midbody; (13) 31–32 transverse dorsal rows; (14) 18–19 transverse ventral rows; (15) 17–20 longitudinal dorsal rows; (16) 8–9 longitudinal ventral rows; (17) a continuous series of small lateral scales separate dorsals from ventral scales; (18) 2–4 posterior cloacal plate scales; (19) two anterior preanal plate scales; (20) four femoral pores per hind limb in males, two in females; (21) preanal pores absent; (22) 7–9 subdigital lamellae on finger IV; 11–14 subdigital lamellae on toe IV; (23) limbs not overlapping when

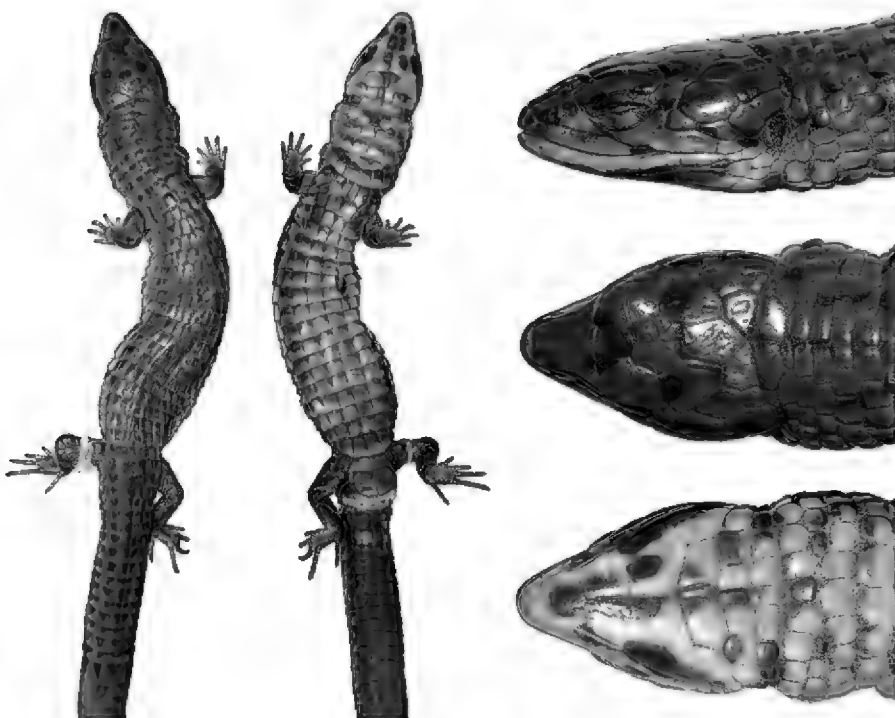


adpressed against body; (24) pentadactyl, digits clawed; and (25) coloration of female in life: dorsum is brown with numerous dark spots distributed irregularly from tip of head to tail, flanks are similar to dorsum, the chin and throat are pale orange with large black spots, venter mostly orange, with black spots on anterior part of ventral scales forming longitudinal lines (Fig. 4); coloration of males in life is unknown; in preservative the dorsum is similar to coloration in life, and venter changes from orange to cream (Fig. 2).

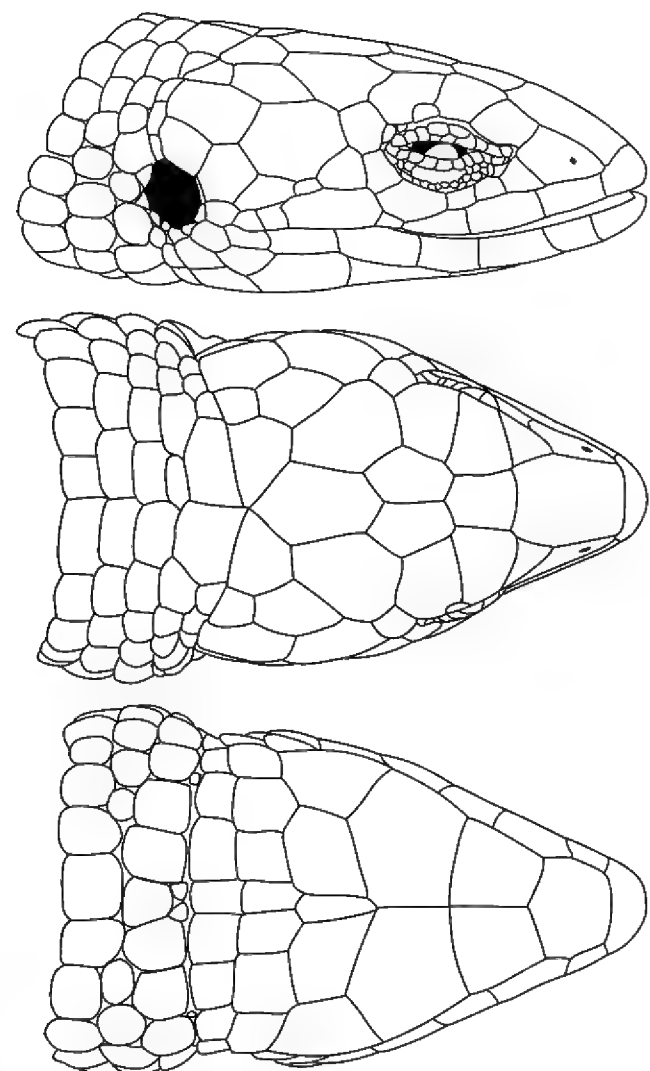
*Petracola amazonensis* can be distinguished from *P. angustisoma* and *P. pajatensis* by lacking a loreal scale (loreal scale present in *P. angustisoma* and *P. pajatensis*); from *P. labioocularis* by lacking precloacal pores and posterior subocular is not elongated downward (precloacal pores present and posterior subocular is elongated downward and separates supralabials in *P. labioocularis*); from *P. waka* by having two genials in contact, first superciliary scale, and venter is orange with black spots forming transverse bands (three genials in contact, four continuous superciliary scales, and venter is cream with some small, black spots in *P. waka*); from *P. ventrimaculatus* by having a maximum SVL in males of 43.0 mm, dorsum dark brown with some black spots not forming bands, and first superciliary only (maximum SVL in females 59.0 mm, dorsum light brown with continuous black dorsal bands, and 2–3 discontinuous superciliaries in *P. ventrimaculatus*).

**Description of the holotype.** Adult female, snout–vent length (SVL) 43.0 mm, tail length 42.3 mm (regenerated); head scales smooth, without striations or rugosities; rostral scale wider (1.5 mm) than tall (0.8 mm), in contact with frontonasal, nasals, and first supralabials; frontonasal longer (2.5 mm) than wide (1.7 mm), longer than frontal scale, widest in the middle, in contact with rostral, nasal, first superciliary, and frontal; prefrontal absent; frontal longer than wide, pentagonal,

in contact with first supraocular and frontoparietals; frontoparietal paired, polygonal (hexagonal), in contact with frontal, supraoculars, parietals, and interparietals; two supraoculars, in contact with superciliaries, frontal, frontoparietals, interparietal, and postoculars; parietals polygonal (irregular heptagon), in contact with frontoparietals, posterior supraocular, postocular, interparietal, temporals, supratemporals laterally, and with postparietals posteriorly; interparietals hexagonal, in contact with frontoparietals anteriorly, parietals laterally, and with postparietal posteriorly; two polygonal postparietals, joined in the middle by a small surface. Nasal scale entire, longer than high, in contact with first supralabial; loreal scale absent; left side with first superciliary, on right side with a posterior rudimentary posterior superciliary, first superciliaries expand on dorsal surface of head; two small preoculars; frenocular trapezoidal in contact with second supralabial; palpebral disc entire and transparent; three suboculars on right side and two on left side; two postoculars; temporals and supratemporals smooth, polygonal; four supralabials anterior to the posteroventral angle of the suboculars. Mental wider than long, in contact with the first infralabial and postmental posteriorly; postmental single, polygonal (irregular pentagonal), in contact with first and second infralabials, and first pair of genials; four genials in contact; three transversal rows of pregular scales, in the anterior row they are large; five rows of gular scales, quadrangular and circular. Dorsal scales rectangular with blunt edges, juxtaposed, smooth, 32 transverse rows; 17 longitudinal dorsal rows at midbody; a continuous series

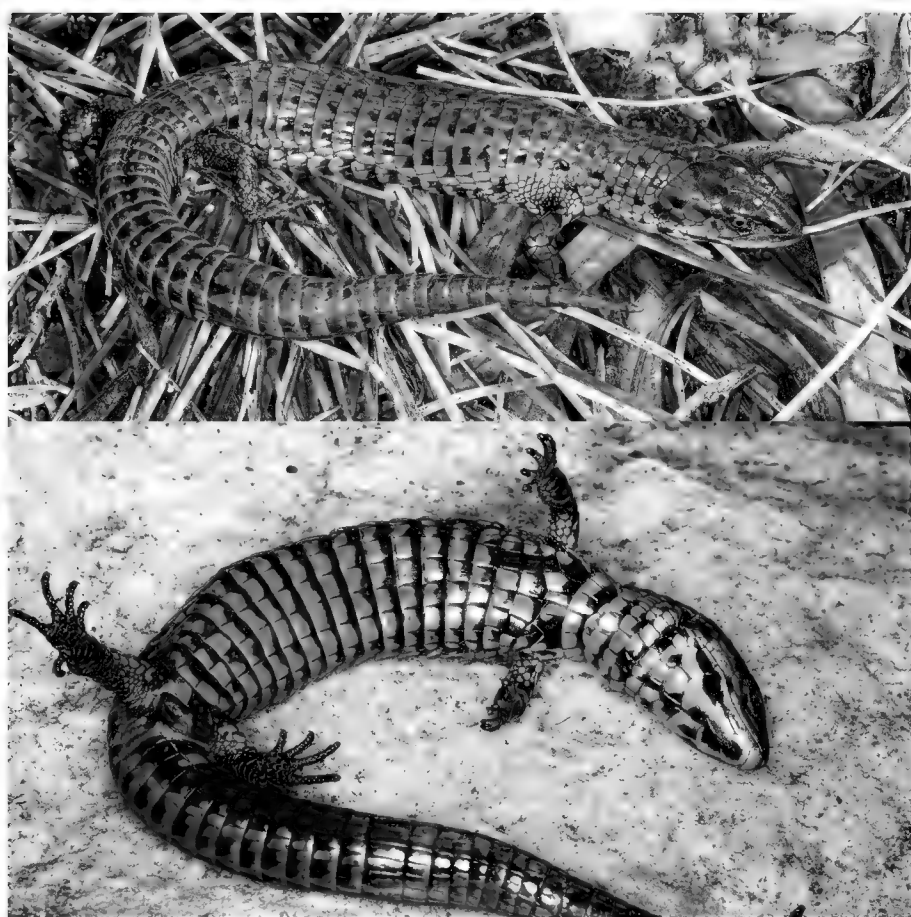


**Fig. 2.** Holotype of *Petracola amazonensis*, female MUBI 11485 (SVL = 43.0 mm, TL = 42.3 mm).



**Fig. 3.** Drawings of lateral, dorsal, and ventral views of the head of the holotype (MUBI 11485) of *Petracola amazonensis*.

of small lateral scales; reduced scales at limb insertion region; 18 transverse ventral rows; eight longitudinal ventral rows at midbody; anterior and posterior preanal plate paired; scales on the tail rectangular, subimbricate, and smooth; ventral scales quadrangular, juxtaposed, and smooth. Limbs pentadactyl; digits clawed; dorsal brachial scales polygonal, imbricate, and smooth with blunt edges; ventral brachial scales small, rounded, and smooth; dorsal antebrachial scales polygonal, imbricate and smooth; ventral antebrachial scales rounded, smooth, smaller than dorsal; dorsal manus scales polygonal, smooth, imbricate; palmar scales small, rounded, and domelike; dorsal scales on fingers smooth, quadrangular, imbricate, two on finger I, three on II, five on III, five on IV, and four on V; two subdigital lamellae on finger I, five on finger II, seven on finger III, seven on finger IV, five on finger V; scales on anterodorsal surface of thigh polygonal, smooth, imbricate; scales on posterior surface of thigh small, rounded, and separated; scales on ventral surface of thighs polygonal with blunt edges, smooth, imbricate, polygonal and juxtaposed; two femoral pores on each thigh; scales on anterior surface of crus polygonal, smooth, imbricate, decreasing in size distally; scales on posterodorsal surface of crus smooth, polygonal, and imbricate; scales on ventral surface of crus polygonal, enlarged, smooth, and imbricate; scales on dorsal surface of feet polygonal, smooth, and imbricate; scales on ventral surface of feet rounded, small, and domelike; dorsal scale of toes smooth, imbricate, two on toe I, four on toe II, five on toe III, six on IV, five on toe V; four subdigital lamellae on toe I, seven on toe II, nine on toe III, 13 on toe IV, eight on toe V. Coloration in life was described in diagnosis; in preservative, dorsum, dorsal surface of head, neck, arms, and legs brown with irregular, black spots; venter, chin, neck, arms, and legs gray with black spots, on venter black spots form transverse bands (Fig. 4).



**Fig. 4.** Holotype in life of *Petracola amazonensis* from Upa (MUBI 11485, SVL = 43.0 mm, TL = 42.3 mm, female).

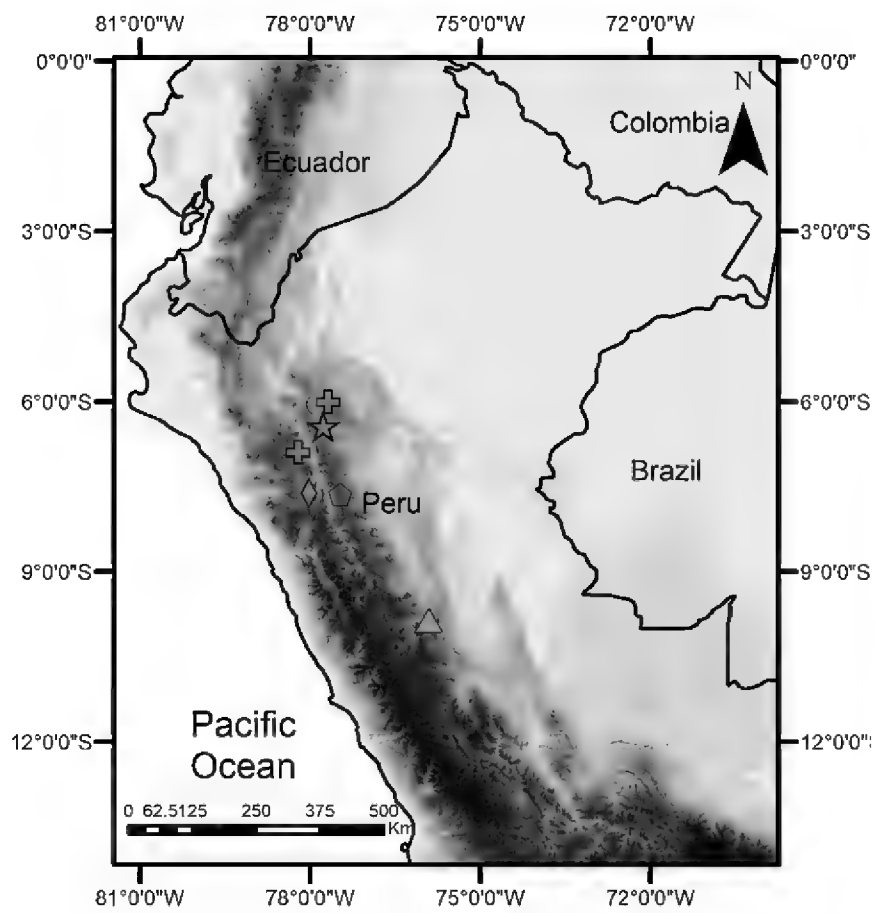
**Variation.** The most notable variation was the number of infraoculars: adult female with 2–3 (left-right), juvenile male with 1–2, and juvenile female with 3–3; adult female with a rudimentary posterior superciliar on the right side; juvenile male with three anterior infralabials on the right side and three postparietals; and adult female with 25 scales around body and 28 on juveniles.

**Distribution and ecology.** *Petracola amazonensis* is only known from the type locality, Upa near Yurumarca, from 3,020–3,250 m asl (Fig. 5), District of Chiliquin, Province of Chachapoyas, Department of Amazonas (Fig. 6). All specimens were found in grassland during March (rainy season). The specimen MUBI 11473 was found under rocks, MUBI 11474 inside bromeliads of the genus *Tillandsia*, and MUBI 11485 walking on grassland near a creek and a forest. *Petracola amazonensis* is likely diurnal and semifossorial. Syntopic Squamata species include *Stenocercus orientalis*. Tree vegetation is dominated by *Podocarpus* (Podocarpaceae), *Alnus* (Betulaceae), *Weinmannia* (Cunnoniaceae), *Ceroxylon* (Arecaceae) and *Hyeronima* (Euphorbiaceae). Dominant species in the shrub layer include *Macrocarpaea* (Gentianaceae), *Munnozia* (Asteraceae), *Chusquea* (Poaceae), and *Piper* (Piperaceae); and herbs *Anthurium* (Araceae), *Tillandsia* (Bromeliaceae), orchids (Orchidaceae) and *Peperomia* (Piperaceae).

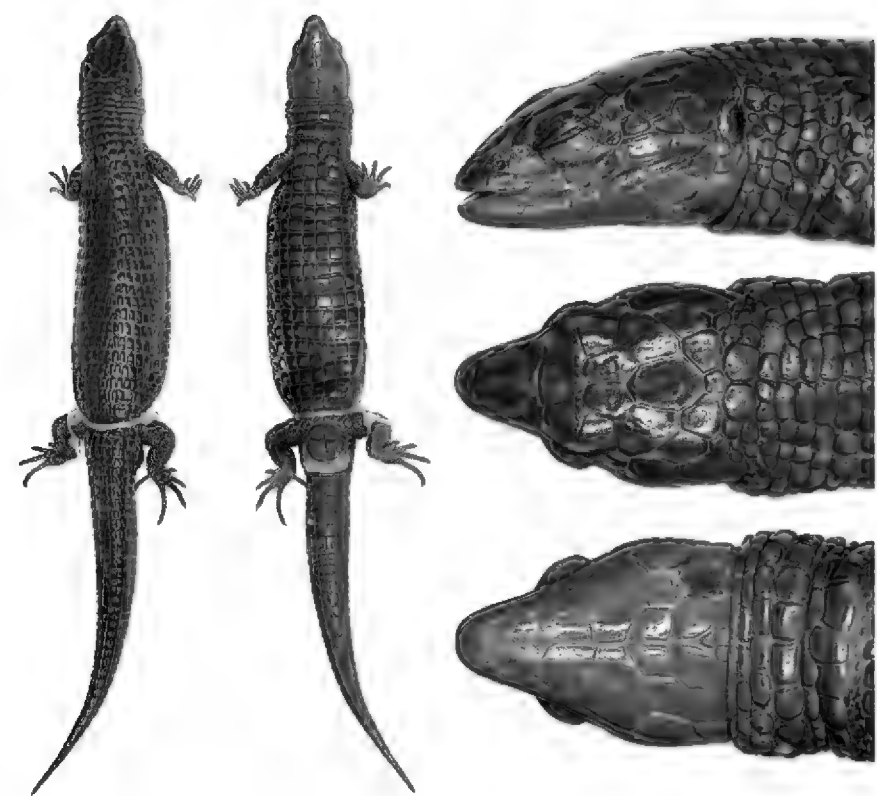
**Conservation.** *Petracola amazonensis* was found in a small area in the district of Chiliquin (Fig. 5), and we suspect it might be endemic to the Department of Amazonas. The type locality is 2.5–3.0 km from the Private Conservation Area “Comunal San Pablo - Catarata Gocta,” and it is very likely that the species is distributed within this conservation area. In general, the habitat where we conducted our herpetological surveys was in an acceptable state of conservation in May 2012. Given the lack of knowledge regarding its geographic distribution, we recommend that *P. amazonensis* be categorized as Data Deficient in the Red List of the International Union for Conservation of Nature (IUCN 2022).



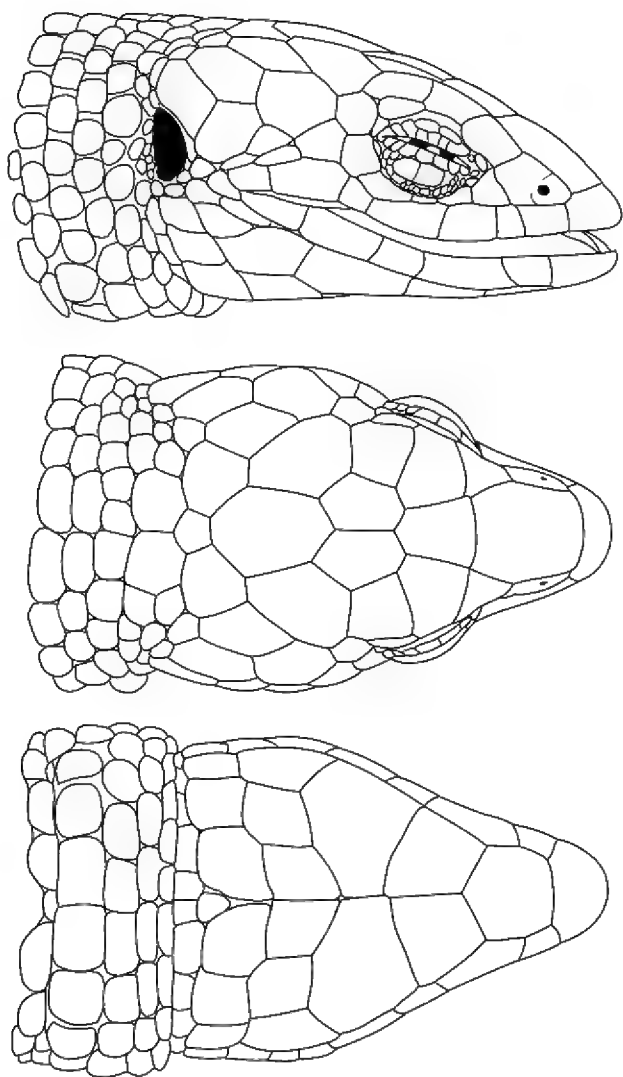
**Fig. 5.** Type locality of *Petracola amazonensis*, Upa, District of Chiliquin, Province of Chachapoyas, Department of Amazonas.



**Fig. 6.** Map showing the type localities of *Petracola* species: *Petracola amazonensis* (blue cross), *P. angustisoma* (red circle), *P. labioocularis* (light blue triangle), *P. pajatensis* (green pentagon), *P. shurugojalcapi* (yellow star), *P. ventrimaculatus* (purple cross), and *P. waka* (orange diamond).



**Fig. 7.** Holotype of *Petracola shurugojalcapi*, adult female PFAUNA 431 (SVL = 51.0 mm, TL = 39.0 mm).



**Fig. 8.** Drawings of lateral, dorsal, and ventral views of the head of the holotype (PFAUNA 431) of *Petracola shurugojalcapi*.



**Fig. 9.** Holotype in life of *Petracola shurugojalcapi* from La Jalca Grande (PFAUNA 431, SVL = 51.0 mm, TL = 39.0 mm, adult female).



*Petracola shurugojalcapi* sp. nov.

urn:lsid:zoobank.org:act:2C3D891D-C75F-4B48-8951-F7870CCE4A09

**Holotype.** PFAUNA 431, adult female (Figs. 7–9) from Área de Conservación Privada Llamapampa-La Jalca, District of Jalca Grande, Province of Chachapoyas, Department of Amazonas, Peru (6°25'36" S; 77°45'56" W; 2,990 m asl), collected by Victor Vargas on 30 May 2013.

**Paratypes.** Seven specimens: Two adult males (PFAUNA 427, MUBI 17727), subadult male (PFAUNA 432), and two adult female (PFAUNA 429, MUBI 17726) from the same place as the holotype. A male (PFAUNA 430) and female (PFAUNA 433) were collected near the type locality (6°25'36" S; 77°45'56" W; ca. 2,990 m asl).

**Etymology.** The specific epithet, *shurugojalcapi*, treated as a noun in apposition, is a combination of two local words: “shurugo” the local name for a gymnophthalmid lizard and “jalcapi” that means “from Jalca” in the Quechua language. The specific name was proposed by the inhabitants of La Jalca Grande.

**Diagnosis.** *Petracola shurugojalcapi* is diagnosed based on the following combination of characters: (1) frontonasal longer than frontal; (2) nasoloreal suture absent; (3) two supraoculars; (4) two discontinuous superciliaries, first expanded onto dorsal surface of head; (5) two postoculars; (6) palpebral disc transparent, divided vertically in two; (7) 3–4 supralabials anterior to the posteroventral angle of the subocular; (8) four anterior infralabials; (9) four genials in contact; (10) three rows of pregulars; (11) dorsal body scales rectangular, smooth, juxtaposed; (12) 29–32 scales around midbody; (13) 31–33 transverse dorsal rows; (14) 18–21 transverse ventral rows; (15) 19–23 longitudinal dorsal rows; (16) eight longitudinal ventral rows; (17) a continuous series of small lateral scales separating dorsals from ventrals; (18) 2–4 posterior cloacal plate scales; (19) two anterior preanal plate scales; (20) 5–6 femoral pores per hind limb in males, 2–3 in females; (21) preanal pores absent; (22) 8–9 subdigital lamellae on finger IV; 13–15 subdigital lamellae on toe IV; (23) limbs not overlapping when adpressed against body; (24) pentadactyl, digits clawed; (25) coloration of males in life is brown or dark brown with or without numerous cream spots distributed irregularly on flanks, and dorsum forming four discontinuous transversal lines, venter immaculate black or blackish gray; females with brown dorsum, numerous and irregular light brown or cream spot on flanks, venter blackish gray.

*Petracola shurugojalcapi* can be distinguished from *P. amazonensis* by having dorsum brown with irregular dark spots, venter black with lateral cream spots, and two separate superciliaries (dorsum brown or dark-brown with irregular cream spots, venter orange with black spots forming transversal bands, and only first superciliary present in *P. amazonensis*); from *P. angustisoma* and *P. pajatensis* by not having a loreal scale (loreal scale present

in *P. angustisoma* and *P. pajatensis*); from *P. labioocularis* by lacking precloacal pores and by having the posterior subocular not elongated downward (precloacal pores present and by having posterior subocular scale elongated downward and separates supralabials in *P. labioocularis*); from *P. waka* by having the palpebral disc divided vertically, two genial scales in contact, two discontinuous superciliary scales, venter black (palpebral disc entire, three genials in contact, four continuous superciliary scales, venter cream with small black spots in *P. waka*); from *P. ventrimaculatus* by having a maximum SVL in males of 51.0 mm, dorsum dark brown or black with some cream spots not forming bands, and venter dark with lateral cream spots (maximum SVL in males 71.1 mm, dorsum light brown with continuous black longitudinal bands, and venter cream with bold black transversal band in *P. ventrimaculatus*).

**Description of the holotype.** Adult female, snout–vent length (SVL) 51.0 mm, tail length 39.0 mm (regenerated), head scales smooth, without striations or rugosities; rostral scale wider (2.0 mm) than tall (0.9 mm), in contact with frontonasal, nasals, and first supralabials; frontonasal longer (2.5 mm) than wide (2.1 mm), longer than frontal scale, widest in the middle part, in contact with rostral, nasal, first superciliary, and frontal; prefrontal absent; frontal longer than wide, pentagonal, in contact with first superciliary, first supraocular, and frontoparietals; frontoparietal paired, polygonal (hexagonal), in contact with frontal, supraoculars, parietals, and interparietals; supraoculars two, in contact with superciliaries, frontal, frontoparietals, interparietal, and postoculars; parietals longer than wide, polygonal (irregular heptagon), in contact with frontoparietals and superior supraocular, interparietal, temporals, and supratemporals laterally, and with postparietals posteriorly; interparietals polygonal (irregularly heptagonal), in contact with frontoparietals anteriorly, with parietals laterally, and with postparietal posteriorly; three postparietals, the middle one is smaller than laterals, polygonal. Nasal scale entire, longer than high, in contact with first and second supralabials; nasal suture does not divide the nasal, the right side has upper and lower suture, but the left side only the lower; loreal scale absent; two superciliaries, discontinuous, and first expanded onto dorsal surface of head; two preoculars; frenocular trapezoidal in contact with second and third supralabial; palpebral disc transparent and divided in two; three suboculars; two postoculars; temporals smooth, polygonal; four supralabials anterior to the posteroventral angle of suboculars. Mental wider than long, in contact with first infralabials and postmental posteriorly; postmental single, polygonal (irregular heptagonal), in contact with the first and second infralabials, and the first pair of genials; four genials in contact; three transversal rows of pregular scales; six gular scale rows, quadrangular with rounded corners, and smooth. Dorsal scales rectangular, longer than wide, juxtaposed, smooth, 34 transverse rows; 20 longitudinal dorsal scale rows at midbody; a continuous series of small lateral scales; reduced scales at limb insertion region present; 20

**Table 3.** Morphometric measurements of *Petracola amazonensis* and *P. shurugojalcapi*. \* broken tail, \*\* regenerated tail.

	<i>P. shurugojalcapi</i>					<i>P. amazonensis</i>
	PFAUNA 431	PFAUNA 427	PFAUNA 430	PFAUNA 429	MUBI 17727	MUBI 11485
	Holotype	Paratype	Paratype	Paratype	Paratype	Holotype
Sex	Female	Male	Male	Female	Male	Female
SVL	51.0	48.5	44.0	47.4	50.8	43.0
LAL	26.7	24.5	24.6	26.3	26.2	21.6
LSA	15.5	19	15	14.8	18.2	14.8
TL	39.0 (**)	65.9 (**)	52.9	7.4 (*)	32.4 (**)	42.3
HL	9.3	10.7	8.9	8.4	10.5	9.3
HW	6.8	8.2	6.9	6.2	8.1	5.6
HH	5.3	6.3	5.4	5.1	6.1	4.6
FR	1.9	2.0	1.9	1.4	2	1.4
FN	2.6	2.7	2.1	2.5	2.6	2.5

transverse ventral scale rows; eight longitudinal ventral scale rows at midbody, lateral scales slightly smaller; anterior and posterior preanal plate scales paired; scales on tail rectangular, slightly subimbricate, and smooth; ventral scales quadrangular, juxtaposed, and smooth. Limbs pentadactyl; digits clawed; dorsal brachial scales polygonal, imbricate, and smooth; ventral brachial scales rounded, separate, and smooth; dorsal antebrachial scales polygonal, imbricate and smooth; ventral antebrachial scales rounded, separate, smooth, smaller than dorsal; dorsal manus scales polygonal, smooth, imbricate; palmar scales small, rounded, separate, and dome-like; dorsal scales on fingers smooth, quadrangular, imbricate, two on finger I, five on II, five on III, five on IV, and four on V; five subdigital lamellae on finger I, eight on finger II, nine on finger III, nine on finger IV, seven on finger V; scales on anterodorsal surface of thigh polygonal, smooth, imbricate; scales on posterior surface of thigh small, rounded, and separated; scales on anteroventral surface

of thigh polygonal, smooth, imbricate and posteroventral surface of thigh small, polygonal and juxtaposed; two femoral pores in both thighs; scales on anterior surface of crus polygonal, smooth, separated, decreasing in size distally; scales on posterodorsal surface of crus smooth, polygonal, separated; scales on ventral surface of crus polygonal, enlarged, smooth, and imbricate; scales on dorsal surface of toes polygonal, smooth, and imbricate; scales on ventral surface of toes rounded, small and domelike; dorsal scale of toes smooth, imbricate, two on toe I, five on toe II, six on toe III, eight on IV, seven on V; five subdigital lamellae on toe I, eight on toe II, 11 on toe III, 14 on toe IV, ten on toe V. Coloration in life, dorsum, dorsal surface of head, neck, arms, and legs brown; lateral sides of dorsum and tail with many small and irregular, cream spots; venter, ventral surface of head, neck, arms, and legs dark gray, flanks have intense cream spots. Coloration in preservative as in life, but less intense.

**Variation.** Adult male MUBI 17727 has two suboculars on the right side, males have 9–12 temporal scales and females 6–9, males are more robust than females; n paratype PFAUNA 432, the nasal suture scale does not divide the nasal, but connects inferiorly to the nostril; in MUBI 17727, the nasal suture connects inferiorly and superiorly to the nostril; and the nasal sutures of the other paratypes do not connect with the nostril and extend posteriorly to middle part of the nostril. Morphometric characters vary by sex and are shown in Table 3.

**Distribution and ecology.** *Proctopous shurugojalcapi* is known only from the type locality, Área de Conservación Privada Llamapampa-La Jalca, from 2,940–2,990 m asl (Fig. 10), District of La Jalca, Province of Chachapoyas, Department of Amazonas (Fig. 6). All specimens (eight) were found during diurnal surveys from 10:00 to 14:00 h. The new species was found in sympatry with



**Fig. 10.** Type locality of *Petracola shurugojalcapi*, Área de Conservación Privada Llamapampa-La Jalca, District of la Jalca Grande, Province of Chachapoyas, Department of Amazonas.

*Stenocercus* sp., *Liophis* sp., and frogs *Gastrotheca monticola*, *Pristimantis schultei*, *P. cf. corrugatus*, *P. sp.*, and *Centrolene* sp. The habitat of *P. shurugojaicapi* is dominated by trees of the genera *Weinmannia*, *Clusia*, and *Symplocos*, and shrubs of the family Melastomataceae.

**Conservation.** *Petracola shurugojaicapi* was found during field studies in support of the establishment of the Área de Conservación Privada Llamapampa-La Jalca. The Conservation Area was established on 17 April 2015, protecting more than 26,000 ha of montane forest and wet grasslands. However, this important area is not exempt from threats such as deforestation and land use changes associated with local subsistence farming, ranching, and forest fires. Although available data indicate that this species could have a restricted distribution, adjacent areas remain unexplored and could host additional populations. Therefore, we recommend that *P. shurugojaicapi* be categorized as Data Deficient in the Red List of the International Union for Conservation of Nature (IUCN 2022).

## Discussion

Our ML phylogenetic analysis recovered the monophyly of *Petracola* with respect to a clade including *Cercosaura*, *Cercosaura manicata boliviana*, *Dendrosauridion*, *Proctoporus*, *Potamites*, and *Wilsonosaura*, a result that is congruent with previous studies (Moravec et al. 2018; Rojas-Runjaic et al. 2021; Mamani et al. 2022). All generic lineages were recovered with high support, except *Proctoporus* and *Pholidobolus*. The genus *Proctoporus* has not been conclusively defined, with some studies supporting its monophyly (e.g., Goicoechea et al. 2012; Mamani et al. 2022; Sánchez-Pacheco et al. 2018; this study), while others do not (e.g., Rojas-Runjaic et al. 2021; Torres-Carvajal et al. 2016; Vásquez-Restrepo et al. 2020). In fact, the topologies of phylogenetic trees differ depending on the methods of phylogenetic reconstruction (Bayesian inference and Maximum Likelihood; Mamani et al. 2022; Moravec et al. 2018). Sánchez-Pacheco et al. (2018) showed that *Proctoporus* is monophyletic when using Maximum Parsimony approximation with either the combined data set of DNA + morphology or the dataset of DNA only. Sánchez-Pacheco et al. (2018) also recovered the monophyly of *Oreosaurus* (including *O. serranus*). However, recent studies showed that *Oreosaurus* is not monophyletic (e.g., Mamani et al. 2022; Rojas-Runjaic et al. 2021). Despite conflicting results, progress from studies using molecular phylogenetic analyses have improved tree topologies overall.

Our phylogenetic analysis recovered multiple diagnosable lineages within *Petracola*, including *P. amazonensis*, *P. shurugojaicapi* (UB=100), *P. ventrimaculatus* (UB=100), and the *P. waka* species complex (UB=100). This preliminary result shows that the species from the right side of the DVMR are an independent lineage with respect from those of the left side (*P. ventrimaculatus* and *P. waka*). However, our sampling

is considered as only preliminary (including only two species) and should be taken with caution. Finally, the phylogenetic position of two species that inhabit the right side of the DVMR, *P. angustisoma* and *P. pajatensis*, is unknown. If our hypothesis is correct, *P. angustisoma* and *P. pajatensis* should form a monophyletic lineage together with *P. amazonensis* and *P. shurugojaicapi*.

Despite the low number of localities sampled, our results supported the hypothesis proposed by Kizirian et al. (2008) that *P. ventrimaculatus* and *P. waka* are cryptic species complexes. Likewise, the populations of *P. waka* and *P. ventrimaculatus* are independent lineages at the species level with high genetic distance and should be recognized as such (Fig. 1, Table 2). Furthermore, we describe two of these species collected on the right side of the DVMR, which increases the diversity of the genus to seven species. The first available sequence of *P. waka* in GenBank (named as *Proctoporus* sp (KU212687) by Castoe et al. 2004) was collected from Abra Gelic, a remote locality (80 km) north of the type locality (Cajabamba), and we added samples from the Cajabamba and Baños del Inca 70 km northwest of the type locality. The molecular evidence suggests that specimens from both Abra Gelic and Baños del Inca belong to undescribed species that will be treated in a separate study. The landscape between these locations is heterogeneous and includes the Huamachuquino River, which is characterized by having arid vegetation (pers. obs.) that could promote vicariance.

Finally, our results suggest that the populations of *Petracola* on the right side of the DVMR are evolutionarily independent from the populations on the left side. These results are similar to those proposed for birds (Hazzi et al. 2018; Weir 2009; Winger and Bates 2015), supporting the hypothesis that the DVMR promotes allopatric speciation of Andean lineages. However, more extensive sampling is needed to determine whether all *Petracola* species on the right side are monophyletic, and to uncover the true diversity of this rarely studied group.

**Acknowledgments.** We thank Cesar Aguilar (MUSM), Pablo Venegas (CORBIDI), the staff of MUBI, and Evaristo Lopez (MUSA) for allowing access to their herpetological collections; and to Tiffany M. Doan and David Kizirian for reviewing our manuscript. JCC is grateful to Alexander Pari, who shared fieldwork and contributed with some lizard collections; JCC field work was funded by Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ). The specimen collection and DNA extraction was authorized by the Servicio Nacional Forestal y de Fauna Silvestre (SERFOR), permits RDG N° 369-2019-MINAGRI-SERFOR-DGGSPFFS, RDG N° 026-2018-MINAGRI-DGGSPFFS, and RDG N° 024-2017-SERFOR/DGGSPFFS. In addition, we thank the NGO Nature and Culture International for its support in the field studies and the Rural Community of Jalca Grande for taking part in the conservation of the forests of the Área de Conservación Privada Llamapampa-La Jalca.



## Literature Cited

- Boulenger GA. 1900. Descriptions of new batrachians and reptiles collected by Mr. P.O. Simons in Peru. *Annals Magazine of Natural History* 6(7): 181–186.
- Castoe TA, Doan TM, Parkinson CL. 2004. Data partitions and complex models in Bayesian analysis: the phylogeny of gymnophthalmid lizards. *Systematic Biology* 53(3): 448–469.
- Doan TM, Castoe TA. 2005. Phylogenetic taxonomy of the Cercosaurini (Squamata: Gymnophthalmidae), with new genera for species of *Neusticurus* and *Proctoporus*. *Zoological Journal of the Linnean Society* 143(3): 405–416.
- Doan TM, Sheffer SA, Warmington NR, Evans EE. 2021. Population biology of the unusual thermoconforming lizards of the Andes Mountains of Peru (Squamata: Gymnophthalmidae). *Austral Ecology* 46: 1,039–1,051.
- Echevarría LY, Venegas PJ. 2015. A new elusive species of *Petracola* (Squamata: Gymnophthalmidae) from the Utcubamba basin in the Andes of northern Peru. *Amphibian & Reptile Conservation* 9(1) [Special Section]: 26–33 (e107).
- Edgar RC. 2004. MUSCLE: Multiple sequence alignment with high accuracy and high throughput. *Nucleic Acids Research* 32(5): 1,792–1,797.
- Futuyma DJ, Kirkpatrick M. 2017. *Evolution*. Sinauer Associates, Sunderland, Massachusetts, USA. 599 p.
- Goicoechea N, Padial JM, Chaparro JC, Castroviejo-Fisher S, De la Riva I. 2012. Molecular phylogenetics, species diversity, and biogeography of the Andean lizards of the genus *Proctoporus* (Squamata: Gymnophthalmidae). *Molecular Phylogenetics and Evolution* 65(3): 953–964.
- Hazzi NA, Moreno JS, Ortiz-Movliav C, Palacio RD. 2018. Biogeographic regions and events of isolation and diversification of the endemic biota of the tropical Andes. *Proceedings of the National Academy of Sciences of the United States of America* 115(31): 7,985–7,990.
- Hoang DT, Chernomor O, Von Haeseler A, Minh BQ, Vinh LS. 2018. UFBoot2: improving the ultrafast bootstrap approximation. *Molecular Biology and Evolution* 35(2): 518–522.
- IUCN. 2022. IUCN Red List of Threatened Species. Available: <https://www.iucnredlist.org>. [Accessed: 30 January 2023].
- Kalyaanamoorthy S, Minh BQ, Wong TKF, Von Haeseler A, Jermini LS. 2017. ModelFinder: fast model selection for accurate phylogenetic estimates. *Nature Methods* 14(6): 587–589.
- Kizirian D, Bayefsky-Anand S, Eriksson A, Le M, Donnelly MA. 2008. A new *Petracola* and re-description of *P. ventrimaculatus* (Squamata: Gymnophthalmidae). *Zootaxa* 1700(1): 53–62.
- Kizirian DA. 1996. A review of Ecuadorian *Proctoporus* (Squamata: Gymnophthalmidae) with descriptions of nine new species. *Herpetological Monographs* 10: 85–155.
- Köhler G, Lehr E. 2004. Comments on *Euspondylus* and *Proctoporus* (Squamata: Gymnophthalmidae) from Peru, with the description of three new species and a key to the Peruvian species. *Herpetologica* 60(4): 501–518.
- Kumar S, Stecher G, Li M, Knyaz C, Tamura K. 2018. MEGA X: molecular evolutionary genetics analysis across computing platforms. *Molecular Biology and Evolution* 35(6): 1,547–1,549.
- Mamani L, Cruz R, Mallqui S, Catenazzi A. 2022. Molecular phylogenetics and comparative examination of voucher specimens reveal two new species of gymnophthalmid lizards (Squamata, Gymnophthalmidae) from the Peruvian Andes, with comments on *Proctoporus guentheri* (Boettger, 1891). *Diversity* 14(3): 215.
- Mamani L, Rodríguez LO. 2022. A new species of Andean lizard, *Proctoporus* (Gymnophthalmidae: Cercosaurinae), from the highland of Parque Nacional Otishi in Peru. *Zootaxa* 5213(1): 75–85.
- Mamani L, Chaparro JC, Correa C, Alarcón C, Salas CY, Catenazzi A. 2020. A new species of Andean gymnophthalmid lizard (Squamata: Gymnophthalmidae) from the Peruvian Andes, and resolution of some taxonomic problems. *Diversity* 12(9): 361.
- Moravec J, Šmíd J, Štundl J, Lehr E. 2018. Systematics of neotropical microteiid lizards (Gymnophthalmidae, Cercosaurinae), with the description of a new genus and species from the Andean montane forests. *ZooKeys* 774: 105–139.
- Rodríguez LO, Mamani L. 2020. A new species of *Petracola* (Squamata: Gymnophthalmidae) from Rio Abiseo National Park, San Martín, Peru. *Amphibian & Reptile Conservation* 14(1) [General Section]: 140–146 (e227).
- Rojas-Runjaic FJM, Barrio-Amorós CL, Señaris JC, De la Riva I, Castroviejo-Fisher S. 2021. Discovery of an additional piece of the large gymnophthalmid puzzle: a new genus and species of stream spiny lizard (Squamata: Gymnophthalmidae: Cercosaurinae) from the western Guiana Shield in Venezuela. *Zootaxa* 4950(2): 296–320.
- Sánchez-Pacheco SJ, Torres-Carvajal O, Aguirre-Peñafiel V, Nunes PMS, Verrastro L, Rivas GA, Rodrigues MT, Grant T, Murphy RW. 2018. Phylogeny of *Riama* (Squamata: Gymnophthalmidae), impact of phenotypic evidence on molecular datasets, and the origin of the Sierra Nevada de Santa Marta endemic fauna. *Cladistics* 34: 260–291.
- Torres-Carvajal O, Lobos SE, Venegas PJ, Chávez G, Aguirre-Peñafiel V, Zurita D, Echevarría LY. 2016. Phylogeny and biogeography of the most diverse clade of South American gymnophthalmid lizards (Squamata, Gymnophthalmidae, Cercosaurinae). *Molecular Phylogenetics and Evolution* 99: 63–75.
- Trifinopoulos J, Nguyen LT, von Haeseler A, Minh BQ.

## Two new species of *Petracola* from Peru

2016. W-IQ-TREE: a fast online phylogenetic tool for maximum likelihood analysis. *Nucleic Acids Research* 44(W1): W232–W235.

Uzzell TM. 1970. Teiid lizards of the genus *Proctoporus* from Bolivia and Peru. *Postilla* 142: 1–39.

Vásquez-Restrepo JD, Ibáñez R, Sánchez-Pacheco SJ, Daza JM. 2020. Phylogeny, taxonomy, and distribution of the Neotropical lizard genus *Echinosaura* (Squamata: Gymnophthalmidae), with the recognition

of two new genera in Cercosaurinae. *Zoological Journal of the Linnean Society* 189(1): 287–314.

Weir JT. 2009. Implications of genetic differentiation in neotropical montane forest birds. *Annals of the Missouri Botanical Garden* 96(3): 410–433.

Winger BM, Bates JM. 2015. The tempo of trait divergence in geographic isolation: avian speciation across the Marañón Valley of Peru. *Evolution* 69(3): 772–787.



**Luis Mamani** is a Peruvian biologist who obtained his M.Sc. degree from the Universidad de Concepción (UdeC) in Chile. Currently, he is a Ph.D. student working on the ecology, systematics, taxonomy, and evolution of gymnophthalmid lizards in the Cordillera de los Andes.



**Víctor J. Vargas García** is a Biologist and Master's student in Applied Ecology. He has more than 10 years of experience in the study of amphibians and reptiles in the Peruvian Andes, participating and collaborating with various expeditions and scientific publications. Currently, he works on several research and conservation projects on threatened amphibians. In addition, he is a researcher associated in the Colección Científica Pro Fauna Silvestre de Ayacucho, a member of the Asociación Herpetológica del Perú, and provides support to the IUCN Amphibian Specialist Group. He currently works at the Servicio Nacional Forestal y de Fauna Silvestre (SERFOR) in Peru.



**Juan C. Chaparro** is a Peruvian Biologist with extensive experience in studying the fauna of all the traditional geographic regions of Peru. Juan graduated in Biological Sciences from Universidad Nacional Pedro Ruiz Gallo, Lambayeque, Peru, and received a Master's degree in Biodiversity in Tropical Areas and Conservation in 2013 from an institutional consortium of the International University of Menendez Pelayo (UIMP-Spain), Universidad Tecnológica Indoamérica (UTIEcuador), and Consejo Superior de Investigaciones Científicas (CSIC-Spain). He is currently the Director and Curator of the Herpetological Collection of the Museo de Biodiversidad del Perú (MUBI), and he works as a consultant in environmental studies. Juan has authored or co-authored 58 peer reviewed scientific papers, notes, book chapters, and books on fauna, especially in herpetology and arachnology, on topics such as taxonomy, biodiversity, systematics, phylogeny, conservation, and biogeography in South America. He is interested in those topics, as well as life history, distributional patterns, and evolution using amphibians and reptiles as biological models.



**Alessandro Catenazzi** is Associate Professor at Florida International University in Miami, USA. He works on the systematics and conservation of Neotropical amphibians and reptiles, and the ecological dimensions of biodiversity. For his first line of research, he works primarily in the Andes and the Amazon. Alessandro collaborates with colleagues in museums and other research institutions in describing new species and developing phylogenies of amphibians and reptiles from the mega-diverse eastern slopes of the Andes. A major theme of his current research is exploring the effects of fungal diseases on the ecology of amphibians, a group that is experiencing staggering biodiversity losses worldwide. After documenting the collapse of a species-rich amphibian assemblage, he is interested in developing strategies to mitigate the impact of the fungal disease chytridiomycosis on the surviving species. Alessandro is an Amphibian Red List Authority and an Associated Researcher with CORBIDI.

